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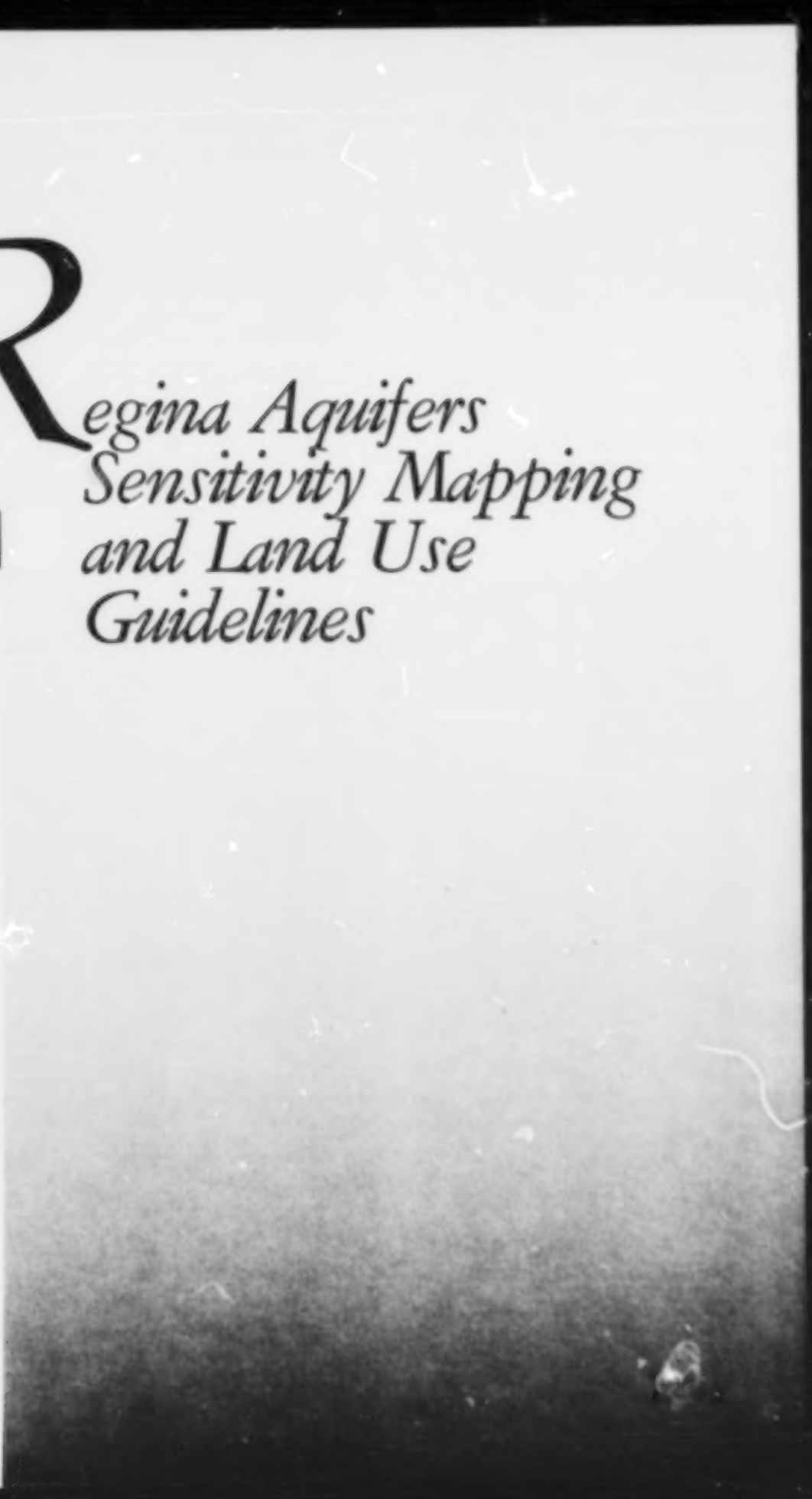
Regina Aquifers Sensitivity Mapping and Land Use Guidelines



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REGINA AQUIFERS SENSITIVITY MAPPING AND LAND USE GUIDELINES

WQ 134

Disclaimer

The contents, conclusions, recommendations and proposed aquifer protection guidelines contained in this report are those of the consultant. They constitute a first attempt at rationalizing the existing scientific knowledge about aquifers into a protection framework. The report and the information on which it is based are regional in nature and have not been intended for drawing site specific inferences. The report is part of a broader attempt by provincial agencies at developing a management and protection plan for aquifers in the Regina area.

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1.0 Introduction

1.1 Overview

The Regina area is underlain by one of the most complex yet heavily developed aquifer systems in Canada. Until 1959, groundwater was the sole source of drinking water for the City of Regina and wells still provide roughly 35% of Regina's water supply (35.2% in 1987, from Calam, 1988). For many surrounding communities, groundwater is the only water source available.

The direct economic benefit of groundwater in the Regina area is difficult to assess. D. Calam (1988) suggests that the availability of groundwater resources realizes savings of tens of millions of dollars in capital and operational costs as compared with supplying Regina with Buffalo Pound water alone. Groundwater is the only water source within the financial means of many of the smaller communities such as Balgonie, White City and Pilot Butte.

The importance of groundwater dictates that this resource must be protected from contamination. To do so is not only environmentally conscientious but also of direct economic benefit to the province. Saskatchewan Environment and Public Safety commissioned this study as one of the steps in a strategy to protect groundwater in the Regina area. It is part of a larger effort undertaken by the department to provide a better understanding of groundwater quality, protect the aquifer, identify existing problems, and implement remedial measures. The purpose of this study is to map sensitive lands over the aquifers, to review the effectiveness of existing legislation and control mechanisms currently in place, and to develop guidelines for protecting the aquifer.

This report is organized into five chapters. The first chapter provides background information, characteristics of the study area, and an outline of the general approach taken for the study. Chapter two presents the sensitivity mapping. Chapter three outlines aquifer protection guidelines. Chapter four discusses current and potential provincial and municipal control mechanisms. Chapter five summarizes the findings of the study.

1.2 Scope

The scope of this study follows the terms of reference under which the work was conducted. A two-part program designed to provide a mechanism for protection of the Regina aquifer complex was conducted. The program components were as follows:

Part A:

- *review past studies and recent hydrogeological data and define zones of hydrologic sensitivity in the study area.*
- *provide recommendations as to the types/categories of developments or land uses which should or should not be considered for various zones.*
- *outline generic aquifer protection measures which should be incorporated into the design of development proposed for the zones, and if appropriate, identify areas where no development should be allowed.*
- *identify existing municipal developments, residential areas and industrial facilities, projected growth areas, and the types of developments likely to be proposed in the study area, and, document conflicts between existing and potential land uses and hydrogeologic sensitivity.*

Part B:

- *Identify existing legislation, bylaws and zoning controls which influence development in the study area, and assess the adequacy of those controls in protecting the groundwater resources.*

- *Recommend changes to existing control mechanisms, if appropriate.*

In accordance with the scope, this study was based entirely on existing data including available maps and reports. In many locations around Regina, test hole data on which maps have been based are sparse, limiting the accuracy of this study to a regional representation. The material presented in this report does not preclude the necessity for detailed hydrogeologic investigation for site specific use.

1.3 Approach

One can distinguish between two approaches to groundwater protection. The first is often called "well-head protection". As the name suggests the purpose of this protection scheme is to delineate zones around existing wells or well fields and to restrict activities within these areas. The idea behind this approach is to allow significant lead time for detection, cleanup and natural biodegradation of contaminants before production wells are affected. The approach is particularly appropriate for extensive bedrock aquifers with more or less uniform overburden conditions. Numerous jurisdictions in the US and Europe rely on well-head protection as their sole groundwater protection measure.

The second approach to groundwater protection is often referred to as sensitivity mapping, protection mapping, groundwater hazard mapping, or groundwater vulnerability mapping. The purpose of this type of mapping is to identify lands over the aquifer which are more susceptible to contamination than others. The approach is particularly appropriate in complex glacial settings where aquifers are

discontinuous and overburden thicknesses vary significantly to the point of sporadic outcrop of aquifer sands at the surface.

Sensitivity mapping was deemed the preferred approach for groundwater protection in the Regina area and for this study because:

- *it recognizes the significance of protecting groundwater recharge areas in addition to well head areas;*
- *it lends itself to future applications in regional land use planning;*
- *delineating well head protection areas for each of the roughly 1400 wells in the study area is not viable from a regional perspective;*
- *the geology of the Regina area is most complex, making well head delineation cumbersome; and,*
- *sensitivity mapping is becoming the preferred approach for regional studies by other jurisdictions (Ohio State Geologic Survey, personal communication, 1990).*

To address concerns about existing development over aquifers in the Regina area, an inventory of urban/industrial activity was prepared and has been overlain on the sensitivity map. Possible generic protection measures were identified and compared with the current legislation. Strategies were then developed for implementation of aquifer protection in the Regina area.

1.4 Existing Information

Numerous studies have been conducted on the groundwater resources of the Regina area. Lissey (1981) prepared an "Aquifer Contamination Risk Evaluation". The study included a map of ranges 17 to 21 and townships 16 to 20, showing

pollution sensitivity based on the thickness of clay overlying the aquifers. The map identified several areas to be very sensitive to pollution, including lands around Pilot Butte and White City, and lands north of Regina from Armour to Condie.

Mollard et al. (Saskatchewan Urban Affairs, 1979) prepared a map of areas suitable for sewage effluent disposal by infiltration. This map suggested that the areas around Pilot Butte, White City and near Condie were "good" for effluent disposal by infiltration. These studies demonstrate the change in perception which has arisen in recent years. While Mollard felt that exposed sands and gravels were suitable for effluent disposal due to the ease of infiltration into the subsurface, Lissey recognized that disposal of foreign substances in these areas would cause groundwater pollution.

In the early 80's, Saskatchewan Research Council began several years of study to re-evaluate the available groundwater data for the Regina area. The work resulted in an interim report (van der Kamp and Maathuis, 1985) delineating the various water bearing formations and a final report entitled "Comprehensive Evaluation of Groundwater Resources in the Regina Area" (Maathuis and van der Kamp, 1988). This latter study is significant in that it provides the most up-to-date maps of the various major aquifers in the Regina area.

In addition, regional soils maps, surficial geology maps, planning maps, and cultural information maps currently exist and were integrated into the mapping aspect of the study. Existing development plans, zoning maps, provincial acts and regulations, and municipal by-laws were used to examine zoning controls. A complete list of references used in preparation of this study is included at the end of the report.

1.5 Geologic Setting

Geologically, the Regina area is situated in the Western Sedimentary Basin which extends east from the Rocky Mountains through Saskatchewan and into Manitoba.

Bedrock materials in the area consist of marine shales, evaporites and mudstone. Repeated glaciation has left a blanket of stratified glacial drift as the surficial deposits throughout the region. All occurrences of potable groundwater in the Regina area are within this blanket of glacial drift.

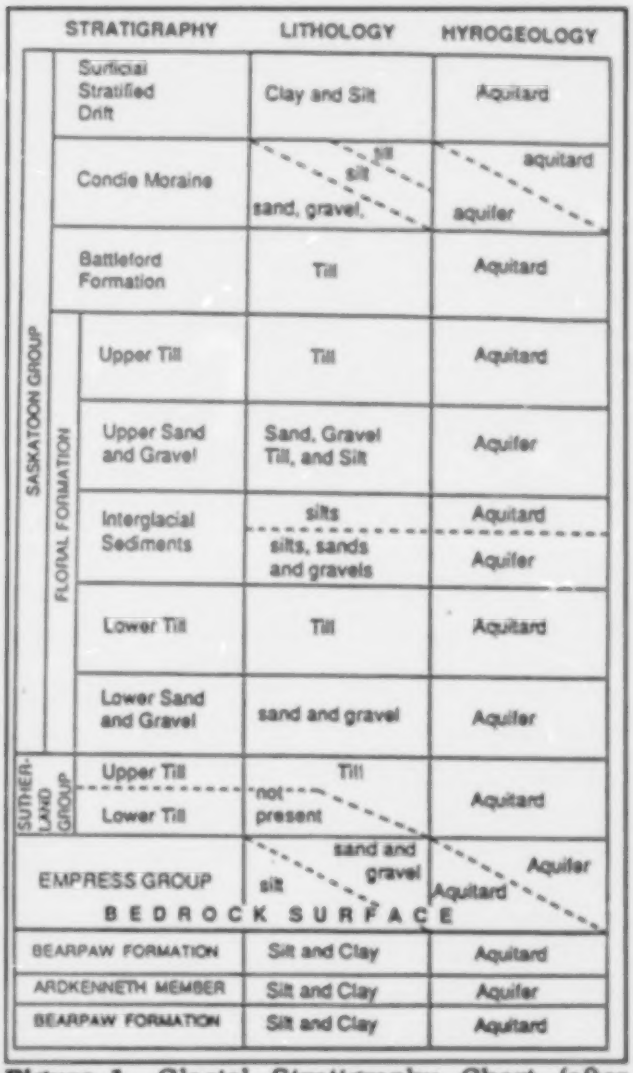

Figure 1. Glacial Stratigraphy Chart (after Maathuis and van der Kamp, 1988).

Thickness of the drift varies from 70 to 180 metres over much of the area with bedrock near surface in the Qu'Appelle Valley. Based on regional mapping and characterization of tills[1], a comprehensive stratigraphic model exists for the area as shown in Figure 1.

Christiansen (1979) divides the glacial sediments into an earlier Sutherland Group and a later Saskatoon Group. The Sutherland Group consists of a clayey, low-carbonate till which forms an aquitard. The Saskatoon Group consists of beds of tills, silts, clays, sands and gravels which have been further categorized by their physical properties and depositional environments.

[1] Glacial till is an unsorted mixture of clay, silt and sand in roughly equal proportions. Stones and boulders are also frequently present. The material originates from glaciers scraping across the land surface and incorporating various materials into the ice. Due to the large percentage of clay, till is usually an aquitard, meaning it does not easily release water into a well and it permits groundwater to move through it only at very slow rates (eg. 1 metre per year). Unfractured till overburden serves a protective function for groundwater similar to clay overburden.

The Floral Formation forms the lower part of the Saskatoon Group. It again has been subdivided into a "Lower Floral" (LF) and "Upper Floral" (UF) unit, each of which consists of a sand and gravel aquifer as well as an overlying till aquitard. In bedrock depression which exist beneath the city, the lower and upper Floral units are further separated by the "Interglacial Sediments" (IGS) which consist of silt as well as sand and gravel forming a third aquifer within the Floral Formation.

Overlying the Floral Formation is a soft and locally discontinuous till known as the Battleford Formation. Overlying the Battleford formation is the Condie Moraine, which consists of silt, minor till as well as sand and gravel, and forms the fourth significant aquifer in the Regina area. Lastly, stratified drift forms the surficial cover over much of the Regina area; the most notable of which are the lacustrine silts and clays known as "Regina Clay".

Due to the number of glacially derived geologic strata, the geology of the Regina area is very complex. Sand and gravel separating the tills are often discontinuous, consisting of truncated gravel channels as well as more or less continuous sheets of outwash. Maathuis and van der Kamp (1988) concluded that due to their complexity, the aquifers are not yet fully understood.

1.6 Major Aquifers

For water management purposes Maathuis and van der Kamp (1988) simplified the complex glacial geology by proposing that the various geologic formations form essentially five major aquifer systems as shown in Figure 2. Based on stratigraphic evidence, water level data and principles of groundwater flow, the five major aquifer systems in the Regina area are the following:

- *The Northern Aquifer, consisting of Upper Floral and Lower Floral sands and gravels (the City of Regina Mound Springs well field is located within this aquifer);*

- *The Zehner Aquifer, also consisting of Upper Floral and Lower Floral sands and gravels (the City of Regina, the Village of Balgonie, the R.M. of Edenwold - Emerald Park subdivision, and numerous rural domestic users draw from this aquifer);*

- *The Regina Aquifer consisting of Upper Floral and Interglacial sands and gravels (the City of Regina and Consumers Co-operative Refinery Ltd. use this aquifer heavily);*

- *The Condie Aquifer, geologically the youngest aquifer in the Regina area, consisting of Condie Moraine sands and gravels (the Village of Pilot Butte, a portion of Village of White City, and rural domestic users access this aquifer);*

- *The Richardson Aquifer, a minor aquifer of poor water quality, consisting of Upper Floral Sands (no municipal users currently utilize this water supply).*

The Condie Aquifer overlies both, the Zehner and the Regina aquifer systems (Figure 2). There are water bearing sands and gravels beneath the Qu'Appelle Valley which form a more or less continuous aquifer along the valley floor which is not delineated on the map.

The sands and gravels found around the communities of Pilot Butte, White City and Condie are outcrops of the dry upper portions of the Condie Aquifer. Outcrops of sand and gravel along the upper reaches of Boggy Creek northeast of Pilot Butte are believed to be part of the Upper Floral sediments of the Zehner aquifer.

1.7 Groundwater Flow

Figure 3 is a schematic flow diagram showing recharge in sandy upland areas.

flow through confined sand layers to the well sites and gravity flow from recharge areas to discharge areas along streams. Although the diagram is schematic, it is analogous to groundwater flow in the Regina area. Elevation differences in the study area approach 200 metres. Areas northeast of Zehner have geodetic elevations of over 670 m.a.s.l. while the Regina plains are only about 570 m.a.s.l. in altitude. The base of the Qu'Appelle Valley is at about 480 m.a.s.l.

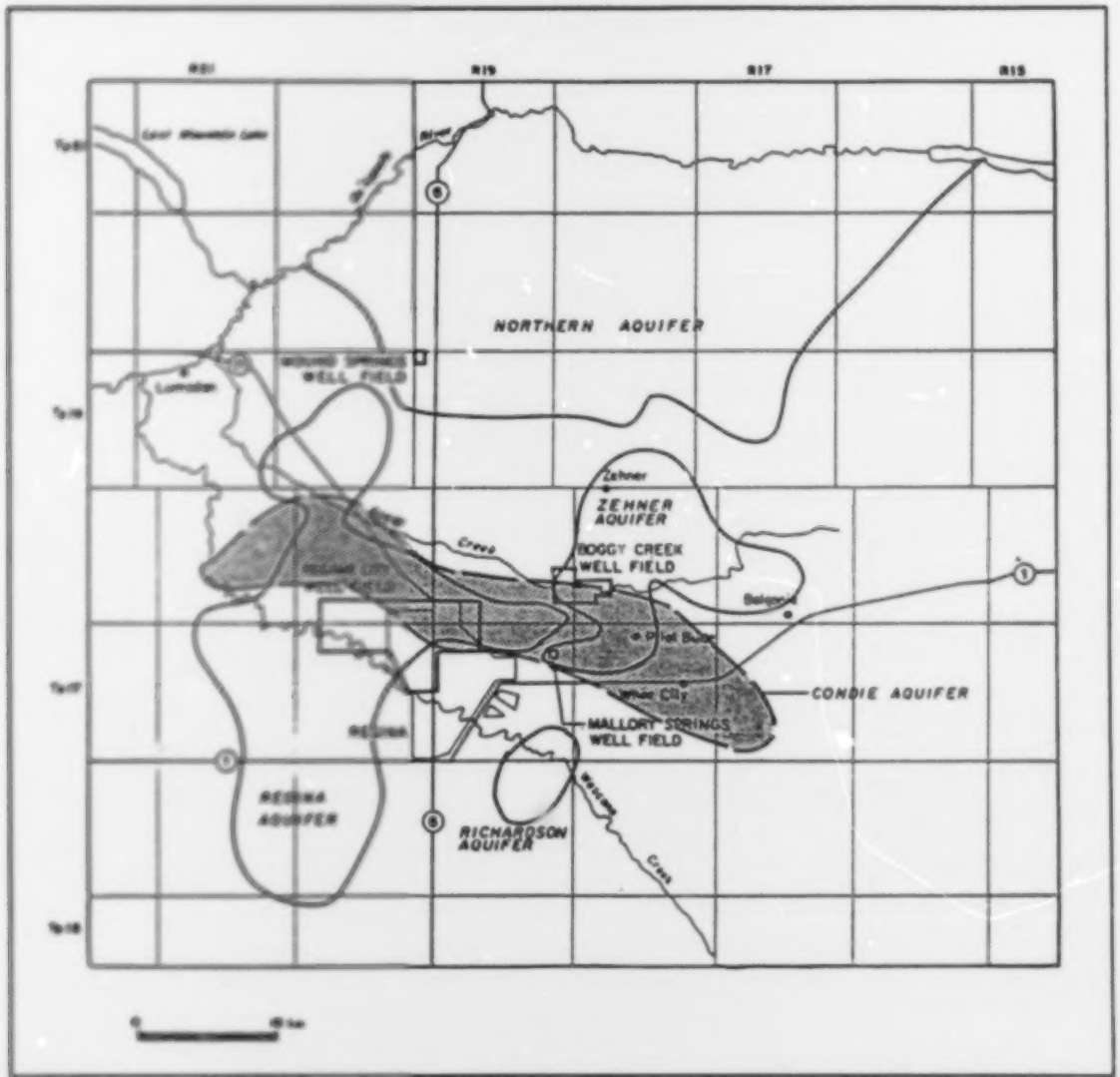

Figure 2. Map of Aquifers (after Maathuis & van der Kamp, 1988). Qu'Appelle Valley sediments also form a major aquifer. Its location coincides with the river course shown.

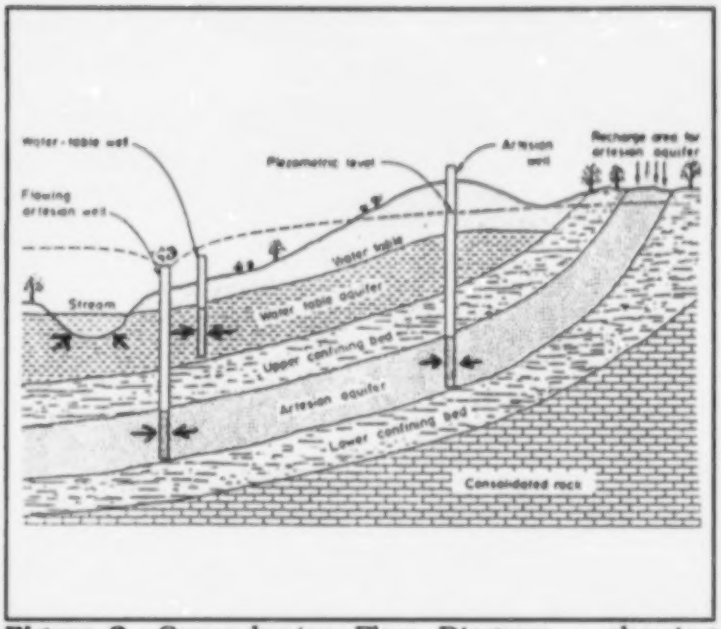

Figure 3. Groundwater Flow Diagram - showing recharge in sandy upland areas, artesian conditions and water table discharge into a stream.

Groundwater flow directions suggest that most recharge occurs in the large sand and gravel outcrops in upland areas: northeast of Zehner; south of Condie; and most significantly, in the Pilot Butte area. Calculations made by Maathuis and van der Kamp, (1988) suggest subsurface flow rates of 400 metres per year or more within the gravel of the Condie Moraine. Evidence of groundwater discharge occurs in the form of springs along Flying Creek, Boggy Creek, Pilot Butte Creek and at several locations along the north wall of the Qu'Appelle Valley.

The various groundwater bearing formations in the Regina area must be seen as a system. Any contamination in a recharge area can potentially travel over long distances towards wells and discharge areas. The nature of the groundwater flow system rationalizes the need for a regional aquifer protection scheme.

2.0 Sensitivity Mapping and Land Use

Sensitivity mapping and land use identification represent the first two steps in this study. This chapter presents the rating system used to classify the study area into sensitivity zones; illustrates the zones on three figures of varying scales; and identifies existing and proposed land uses and associated conflicts.

2.1 Sensitivity Rating

For the purpose of this study it was decided that the thickness, type and protective (permeability) properties of surficial material above the aquifer should form the basis for rating how sensitive particular lands are in terms of groundwater pollution. Since the study is regional in nature, an attempt was made to develop a classification criteria which is simple and can be correlated with information on the existing maps used, such as "depth to aquifer" or "surficial geology".

Lissey (1981) developed a classification system based on extensive testing of clay permeability in the Regina area. Lissey's results suggest permeabilities as low as 1.5 centimetres per year in unweathered clay at depth and as high as 1500 metres per year in desiccated and weathered clay. Lissey argued that permeabilities due to clay weathering are greatest in the upper few metres and that areas with less than 3 metres of Regina Clay cover are "highly sensitive" and areas with no protective cover are "extremely sensitive".

The present study area is larger and covers a wider range of surficial materials for which no permeability data exists. Research conducted on tills and clays suggests that permeabilities can vary by several orders of magnitude. A study by Keller

(1987) suggest that in thin but unweathered till, permeabilities are in the order of 15 cm/year. Work by Lafleur (1987) suggests that in weathered till, permeabilities can be 2 to 4 orders of magnitude greater - in this case possibly 15 metres/year or more. The information suggests that clay and till are similar in permeabilities and protective properties on a regional basis.

The rating criteria developed by Lissey are generally valid in the wider study area. To account for the additional variability in the two materials, Lissey's criterium for 3 metres of clay overburden was increased to 5 metres of clay or till. Undifferentiated clastic sediments such as sands, silts which are not part of an aquifer were considered to offer only half the protection of clay or till. Areas not mapped as part of the major aquifer systems were classified as "sensitivity unknown" rather than "not sensitive" since minor aquifers are known to exist but their extent has not been mapped.

The following is the complete classification criteria developed:

Extreme - *a major aquifer is present which extends to surface and has no protective clay or till overburden; or, a major aquifer is present beneath 0 to 5 metres of undifferentiated overburden of which the upper portion consists of silty or sandy material.*

High - *a major aquifer is present beneath 0 to 5 metres of protective clay or till overburden; or, a major aquifer is present beneath 5 to 10 metres of undifferentiated overburden of which the upper portion consists of silty or sandy material; or, a major aquifer has not been mapped but surficial sands are present which may form local unconfined aquifers of limited extent.*

Moderate - *a major aquifer is present beneath 5 to 10 metres of protective clay or till overburden; or, a major aquifer is present beneath no less than 10 metres of undifferentiated overburden of which the upper portion consists of silty or sandy material.*

Low - *a major aquifer is present beneath no less than 10 metres of protective clay or till overburden.*

Unknown - *no major aquifers have been mapped and the surficial material is clay or till offering a protective cover of unknown thickness; minor aquifers may be present but have not been mapped; more test hole data and mapping is required to better assess the sensitivity of these areas; at most locations sensitivity is expected to be low.*

It should be recognized that the variability in permeability values for clayey materials makes the rationalization of "adequate protective cover" difficult and the classification criteria to some degree arbitrary. Permeability values and the related time of travel for contaminants can only be estimated within two orders of magnitude at best. Under these limitations, the classification criteria is regional in nature. It may or may not be applicable to more rigorous site specific assessments.

The rating system established is relative to the range of overburden encountered in the Regina area. Much of the land in the study area has less than 10 m of clay or till overburden over the aquifer. Other parts of the province have 50 m or more of such overburden. In comparison to these areas, most of the Regina area is relatively sensitive. Extrapolation of the classification criteria to other areas is therefore not possible.

2.2 Sensitivity Mapping

Sensitivity mapping was conducted using existing data and information of hydrogeologic conditions throughout the study area. A total of 15 published maps were consulted to determine aquifer extent as well as the type and thickness of overburden. The maps used include the following:

1 *Elevation of Bedrock Surface (Maathuis and van der Kamp, 1988).*

2 *Extent, depth to and thickness of Condie Moraine Sands and Gravels (Maathuis and van der Kamp, 1988).*

3 *Extent, depth to and thickness of Upper Floral Formation Sands and Gravels (Maathuis and van der Kamp, 1988).*

4 *Thickness of aquitard separating Condie Moraine Sands and Gravels and Upper Floral Formation Sands and Gravels (Maathuis and van der Kamp, 1988).*

5 *Extent, depth to and thickness of Interglacial Sediments (Maathuis and van der Kamp, 1988).*

6 *Extent, depth to and thickness of Lower Floral Formation Sands and Gravels (Maathuis and van der Kamp, 1988).*

7 *Effluent Disposal (Infiltration) (Saskatchewan Urban Affairs, 1979).*

8 *Thickness of Regina Clay (Lissey, 1981).*

9 *Geology and Groundwater Resources of the Regina Area (Christiansen, 1971).*

10 *Surficial Geology of the Regina Area (SRC, 1987).*

11 *The Soils of the Regina Map Area (Ellis et al, 1965).*

12 *National Topographical System, maps 72-I(7,8,9,10).*

Information from the maps that could assist with aquifer sensitivity mapping was entered into a computer data base. This included data from maps 2, 3, 5, 6, and 8. The maps on soils, effluent disposal and surficial geology contain similar information. The most recent and up to date of these, the surficial geology map, was used.

SPANS (spacial analysis software) was used to analyze, amalgamate, and concurrently interpret the source maps. Major stratigraphic units were amalgamated to delineate the overall extent of major aquifers. Depth-to-aquifer maps were used to determine the depth to the first aquifer in any particular location. Surficial geology maps were then used to define overburden types.

Point specific data from the depth-to-aquifer maps were contoured into spatially distributed intervals. A combination of computerized and manual contouring was used to obtain optimum results based on the sparse data density. Maps were then normalized to provide consistent units and intervals from one map to the next. Once all maps were normalized and contoured, SAS data analysis software was used to develop a constraint matrix for concurrent evaluation of all data according to the sensitivity ratings developed. A copy of the program used as the constraint matrix is included in Appendix A.

These procedures resulted in the sensitivity map shown in Figure 4. An enlarged view (Figure 5) shows the sensitive zones in the Pilot Butte area. Figure 6 (in the back cover pocket) shows the zones at a scale of 1:100,000.

It is important to note that these aquifer sensitivity maps are regional in nature. Most source maps were originally compiled from air photos and geologic logs and e-logs. In some portions of the study area, particularly those distant from urban centres, the original data is sparse and source maps in these regions are interpretive. In particular, the SRC maps which outline aquifer extent, are not suitable for site specific use near aquifer boundaries. No attempt should be made to use the source maps or aquifer sensitivity map in place of site specific studies. For additional information on the source maps, referenced sources should be consulted.

The sensitivity map formulated in this report differs from that presented in the Industrial Zoning Review recently prepared for the City of Regina (McDonald et al, 1989). In the McDonald report, sensitivity zoning is based on the presence or absence of the Regina aquifer, and the Condie aquifer. The zoning classification is as follows:

Zone 1	*no aquifers are present.*
Zone 2	*contains the Regina Aquifer only. The aquifer is protected by surficial clay, silt and till, all of which are aquitards.*
Zone 3	*contains the Condie aquifer only, with a clay and silt cover.*
Zone 4	*contains both aquifers separated by a till and overlain by a variable thickness of clay and silt.*
Zone 5	*contains Condie sand to surface.*

In the McDonald classification there is no attempt to qualify the type of overlying surficial geology or the thickness of the protective cover. Since different criteria were used in the two reports, the areas defined by the two classification systems differ. Consideration of type and thickness of the protective cover as presented in this report should be considered the more rigorous approach.

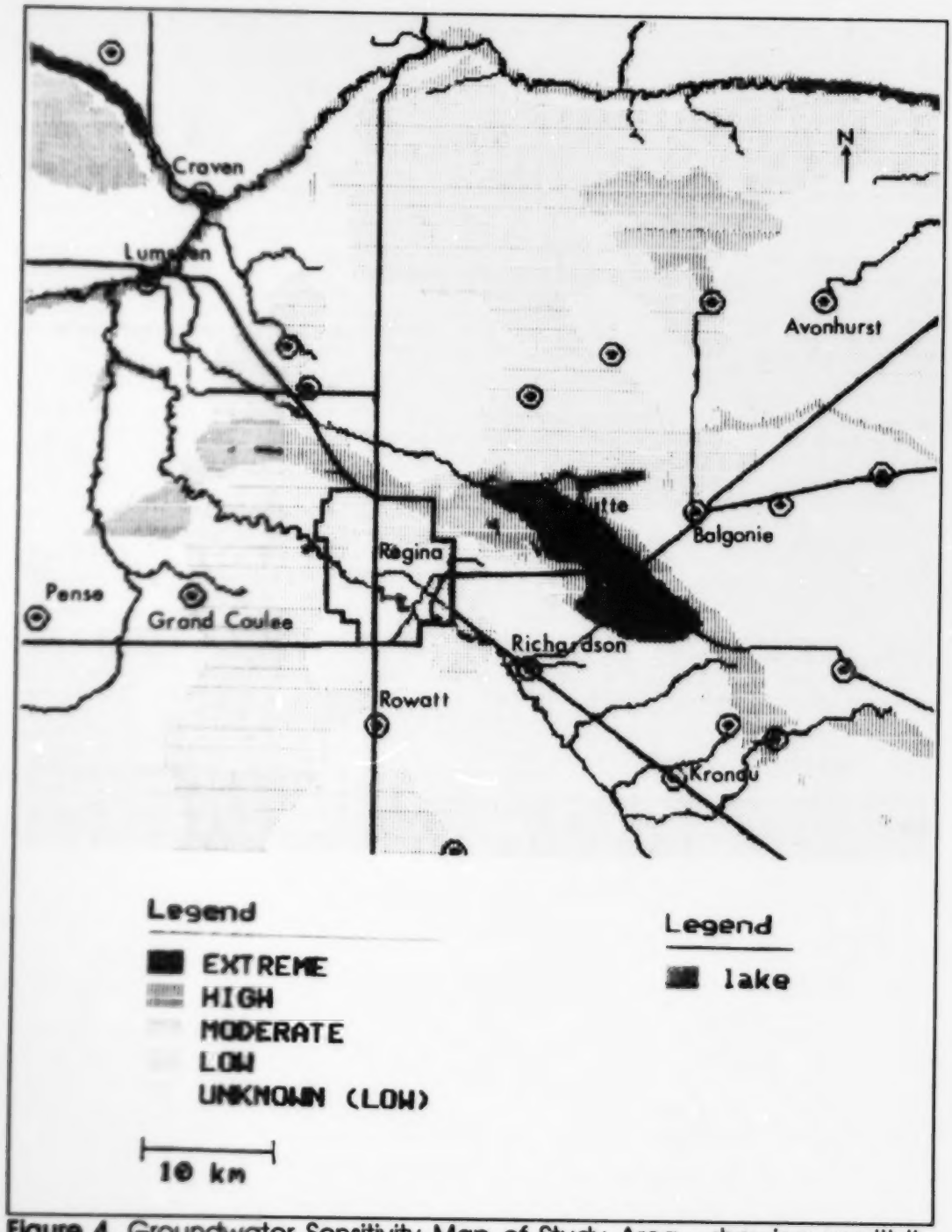

Figure 4. Groundwater Sensitivity Map of Study Area - showing sensitivity zones in relation to highways, streams and communities.

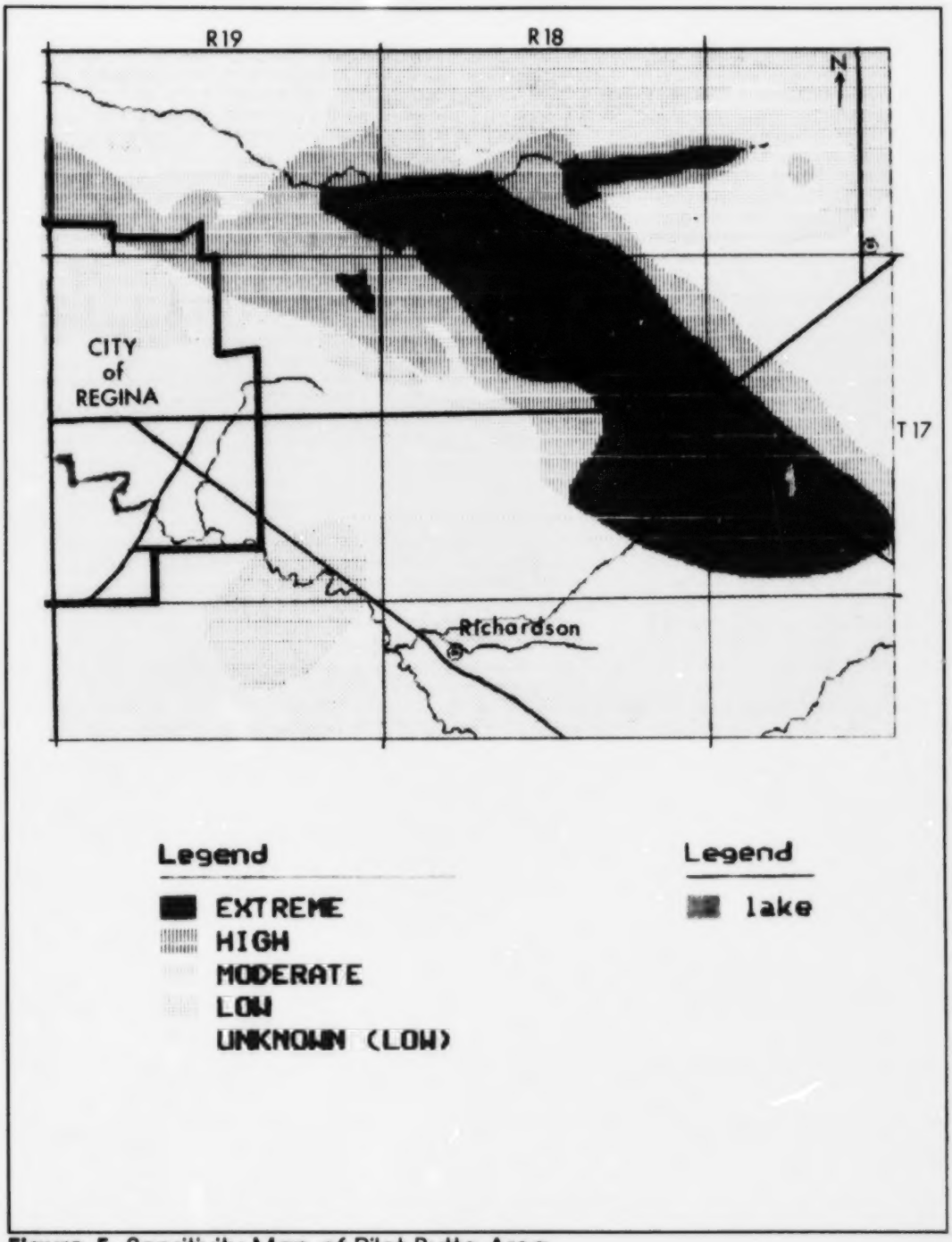

Figure 5. Sensitivity Map of Pilot Butte Area

2.3 Urban/Industrial Land Use

Figures 4 and 5 show various transportation facilities and communities overlying areas sensitive to groundwater contamination. To gain more knowledge of major urban/industrial land uses over the aquifers, an inventory was conducted. At a scale of 1:100,000, Figure 6 (map in back cover) shows an enlargement of the sensitivity zones of Figure 4 as well as the following land use features:

- *Transportation Facilities, including railways, gas and oil pipelines, highways, proposed Regina rail relocation sites and Regina Airport;*
- *Urban Areas, including city limits, towns, villages, hamlets, trailer courts, developed and proposed rural subdivisions;*
- *Industrial Areas, including plant sites, industrial parks and light industrial rural subdivisions;*
- *Sewage Lagoons; and,*
- *Landfill Sites (active).*

Land uses not delineated on Figure 4 and 5 include recreational areas such as golf courses, picnic sites, and parks; farm yards; cemeteries; wells sites; test hole sites; gravel quarries; livestock operations; and, agricultural land uses such as cultivated land, domestic grassland and native prairie. For some applications, mapping land use at a smaller scale of 1:50,000 or possibly 1:10,000 would be advisable.

Land use activities were compiled from various sources, including planning and zoning maps, rural municipality maps, and 1:50,000 scale National Topographic Series (N.T.S.) maps. Representatives for the R.M. of Edenwold and the R.M. of Sherwood were consulted on the not-yet-developed but already subdivided rural land parcels. Sewage lagoon and landfill locations were taken from existing maps and land location records on file with Saskatchewan Environment and Public Safety. Minor discrepancies may exist as a review of Saskatchewan Land Titles

Records was not within the scope of this study.

A review of the Urban/Industrial Land Use Map (figure 6 in back pocket) reveals the following conflicts:

- *Urban/industrial land uses in the Regina area cover both sensitive and non-sensitive areas. The communities of Pense and Balgonie are located in areas of low sensitivity. The communities of Pilot Butte and White City are located over exposed parts of the aquifers where sensitivity is rated as extreme.*

- *Several landfills, sewage lagoons and plant sites throughout the study area are located on highly and extremely sensitive lands. Lumsden has both a sewage lagoon and a landfill in the sensitive Qu'Appelle Valley. The Regina landfill and the nearby sewage lagoon of the Correctional Institute are both located in areas rated as highly sensitive. Lagoons for Pilot Butte, White City, and the Hamlet of Emerald Park are located in areas of extreme sensitivity.*

- *The area immediately north and east of Regina features several areas with high or extreme sensitivity to aquifer contamination. Current residential development trends within the City are to the northwest, posing relatively minor concern. Industrial expansion, however, favours a northerly and easterly trend onto lands with either high or extreme rating.*

- *Information on the Regina Rail Relocation proposal suggests that new rail yards may be located in an area over the aquifer zoned as highly sensitive. The North Regina Industrial Park also covers highly sensitive lands over the aquifer. Ross Industrial Park to the northeast covers lands of low, moderate and high sensitivity.*

- *Subdivided lands and already developed lands in the rural area between Pilot Butte and the City of Regina suggests that additional urban and light industrial growth is probable, primarily along the Trans-Canada Highway.*

The impact which urban/industrial development has had on the aquifer is not fully understood. Maathuis and van der Kamp (1988) suggest that water quality has been affected in several locations. Increasing urban/industrial development over sensitive parts of the aquifer increases the threat of additional aquifer contamination.

3.0 Aquifer Protection

Development of an aquifer protection scheme requires consideration of land uses and related activities as well as consideration of measures which are available to mitigate impacts from these activities. Based on knowledge of aquifer sensitivity, guidelines can be developed for activities which are, or are not, appropriate over given parts of the aquifer.

In this section of the report, some of the land use activities which are of concern to aquifer protection are identified. Also, consideration is given to generic measures which can be employed to protect the aquifer. Possible land use guidelines are then examined and summarized in table format for each of the five sensitivity zones.

3.1 Land Use Concerns

Urban, industrial and agricultural land use pose risks to groundwater quality. Concerns arise from the activity itself and from substances or materials associated with the activities. The following list illustrates categories of land uses, provides examples of typical activities, and outlines the general concerns related to each activity type.

- *Industrial Land Use: Activities include: manufacturing, refining, warehousing, rail yards and airports. Examples are chemical manufacturers; agricultural chemical suppliers; petrochemical industries; petroleum fuel retailers; commercial cleaners; commercial printers and photo developers; auto body repair and paint shops; cleaning of railcars, planes, busses, trucks and other transportation equipment; auto service sector; dairy and beverage industry; institutional facilities; laboratories and waste recyclers. Concerns are that industrial activity substantially increases the potential for introduction of contamination substances into the area.*

- *Urban Land Use: Activities include: housing, retail, commercial, institutions, gas stations, parks, golf courses, and cemeteries. They substantially affect land use, drainage and physiography of the area. Concerns are that urban activity increases the potential for introduction of contaminating substances into the area; and, that the water balance in the subsurface is changed to create new recharge areas. Associated concerns include road paving, street salting, building construction, lawn watering, pile penetration, and pesticide application in parks and golf courses.*

- *Rural Land Use: Activities include: acreages, equipment yards, stock yards, municipal yards, farm yards, feedlots, intensive livestock operations, institutions, transformer stations, community well sites, pesticide retail, elevators, machinery dealers, fertilizer retail, recreational areas, gravel quarries, and borrow pits. Concerns relate to the handling of sewage, waste oil, fuel storage, well drilling and other contaminant risks introduced by these activities. Gravel and borrow pits are of concern because they can remove cover material from the aquifer and create opportunities for concentration and high rate infiltration of surface run-off.*

- *Agricultural Land Use: Activities include native prairie, pasture, dry-land farming, irrigated land, and effluent irrigated land. Concerns include storage of fertilizer, manure and pesticides. Application of fertilizer and pesticide may also be a problem but there is incomplete evidence to support this.*

- *Transportation Land Use: Activities include highways, railways, gas and oil pipelines, and airports. Concerns are that through accidents or breakage spills of contaminants could occur.*

- *Waste Management Land Use: Activities include landfill sites, sewage lagoons, containment ponds and storm ponds. Concerns are that seepage or leaching of contaminants to the aquifer could occur. There is also potential for illegal dumping of materials and waste product.*

3.2 Aquifer Protection Measures

Each land use has associated sources of environmental risk. By recognizing these risk sources, it may be possible to mitigate risk by applying protection technology or improved engineering design. Considered below are various common risk sources and possible mitigative measures which may provide some degree of aquifer protection:

Above Ground Storage Tanks: Use of above ground storage tanks is common for storage of fuels and chemicals. Their use is associated with urban, rural and industrial land uses. Techniques to reduce the risk of spill contamination include the use of liners and dykes. Depending on how rigorously these techniques are applied, a reasonable degree of risk reduction can be achieved. Complete protection from spill contamination in areas of thin protective overburden can only be achieved by avoiding the use of such tanks.

Chemical Use: Use of a multitude of chemicals is associated with urban, rural and industrial land uses. The risk a particular chemical poses to groundwater depends on various physical and chemical properties of the substance as well as quantities used. In Canada, no system exists for rating the risk to groundwater of any particular chemical. Generally however liquids pose a greater threat than dry chemical goods. Liquids are more difficult to contain than dry goods and can penetrate the subsurface without first being dissolved by water. Industry commonly uses the Transportation of Dangerous Goods Classification of hazardous materials. The classification is not directly applicable to assessing hazard to groundwater; however, liquids often fall under classes 3, 5, 6, 8 and 9. For cross-referencing purposes and until a better classification scheme is available, substances in these classes may be considered to pose greater risk than dry substances in classes 1, 2, 4 and 7.

Excavations: Excavations for construction can reduce the effective thickness of protective overburden. In areas where protective overburden is thin (say 5 metres or less), common excavation practices such as constructing basements, trenches, road ditches and land levelling, can significantly effect aquifer sensitivity. Excavation can also alter drainage patterns, causing ponding of water which may lead to unwanted recharge. In areas with 5 metres or less of overburden it would be beneficial to minimize excavation. In areas with 10 or less metres of overburden restricting excavation to 5 metres or less would be advisable.

Waste Containment: Land fills, sewage lagoons, and waste storage areas pose a risk to the aquifer due to possible seepage of the waste into the subsurface. In areas with substantial till or clay overburden (10 metres or more), a natural barrier to such seepage exists. In more sensitive areas, additional protective technology should be applied. Techniques commonly used are installation of clay liners, or impervious artificial liners, which if properly installed will reduce or eliminate seepage.

Land Application of salt and manure: Land application of road salt and manure is associated with agricultural, rural, urban and industrial land uses. Research data on the impact of such applications to groundwater in the prairies is still sparse; however, indications from other regions suggest that, at elevated levels of application, the root zones cannot break down these substances, leading to downward seepage. Until more is known about the impact of land application, it should be avoided in the most sensitive areas altogether. In areas where overburden is thin (5 metres or less), minimizing application would be advisable.

Private Sewage: Private septic tanks can be the cause of nitrate and chloride contamination in the subsurface. Of particular concern is underground seepage disposal of septic tank effluent. In areas with no protective overburden, it is

advisable to use holding tanks instead of underground disposal. In areas where overburden is thin (5 metres or less), above ground disposal using an ejector system would be of benefit. Above ground disposal allows some attenuation of nitrates and minor chlorides in the root zone; and, it maximizes the overburden remaining between the effluent and the aquifer.

Runoff: Agricultural, rural, urban and industrial land uses often have associated storm runoff controls. Runoff in these areas may contain oil or fuels leaked from vehicles or contaminants from numerous major and minor chemical spills. Where runoff is allowed to pond, infiltration into the subsurface will take place. In areas of thin overburden cover (5 metres or less) such ponding could be a source of aquifer contamination. Among land uses where chance of contaminated runoff is particularly high, such as some types of industrial activity, avoiding of ponding may not be adequate. Collection, containment, testing, and possibly treatment of runoff is advisable in these cases.

Spill: A spill of any contaminating substance poses a potential risk to the aquifers. The level of risk is related to the type of substance spilled as discussed in the rationale on chemical use above. In addition, the risk is related to the thickness of protective overburden between the spill and the aquifer. Travel time of contaminants is related to thickness and type of overburden and may vary from hours to years. As a general precaution however, spills in sensitive areas should be excavated immediately.

Underground Storage Tanks: Use of underground storage tanks is common for storage of fuels and chemicals. Their use is associated with urban, rural and industrial land uses. Techniques used to reduce the risk of spill contamination include secondary containment and leak detection systems. Depending on how rigorously this technique is applied, a reasonable degree of risk reduction can be achieved. Complete protection from spill contamination in areas of thin protective overburden can only be achieved by avoiding the use of such tanks. Because it is more difficult to detect and clean up spills from underground storage tanks, their use carries more inherent risk than above ground storage tanks.

Wells, test holes: Drilling of wells and test holes disturbs the subsurface and can provide seepage paths into deep parts of the subsurface and the aquifers. Common practice in the well drilling industry is to partially backfill holes with loose cuttings or to insert a surface plug. The annulus around casings is often left open or backfilled with loose cuttings. Several techniques are available for sealing test holes and well annuli with cement grout or dry bentonite clay powder or pellets. Proper sealing of wells and test holes should occur in any area.

Piles/Geotechnical: In the geotechnical industry it is common to conduct geotechnical test drilling for foundation testing and to install deep piles as support footings. Similar to excavations and well drilling discussed above, piles and geotechnical work disturbs the protective overburden. Sealing techniques or even backfilling is often not carried out. Hole sealing should be done for any drilling activity in any area.

Monitoring: Monitoring can take many shapes and forms. It may include water sampling at the surface or in piezometers, soil testing or keeping inventories of substances received, used, stored and disposed. The general purpose of monitoring is to provide early detection of spills or contamination into the environment. Neglecting to monitor is a risk to aquifers. Design and implementation of a monitoring program should therefore be considered a component of aquifer protection in sensitive areas.

To allow subsequent reference to the above rationale on risk sources and possible mitigative measures, the following summary list has been compiled. A code has been assigned to each source and option.[2]

Risk Source	Code		Mitigation Option
Above Ground Storage Tanks	*A1*	-	*do not allow storage tanks*
	A2	-	*secondary containment by dyke and liner*
Chemical Use	*C1*	-	*do not allow hazardous materials except those essential to run operation*
	C2	-	*do not allow hazardous liquids except those essential to run operation*
Excavations	*E1*	-	*keep excavation to a minimum*
	E2	-	*no excavation below 3 metres depth*
Waste Containment	*I1*	-	*use impervious liners for all containment*
	I2	-	*use clay liners for all containment*
Land Application of salt and manure.	*L1*	-	*avoid land application*
	L2	-	*minimize application*
Private Sewage	*P1*	-	*allow holding tanks only*
	P2	-	*above ground disposal only*
Runoff	*R1*	-	*contain all site runoff*
	R2	-	*avoid ponding and provide adequate drainage*
Spill	*S1*	-	*excavate immediately and contain material*
Underground Storage Tanks	*U1*	-	*do not allow underground storage tanks*
	U2	-	*use secondary containment and leak detection*

[2] No attempt was made to make the mitigative options which are put forward compatible with existing regulations and guidelines. Where such guidelines apply, they should be duly consulted. Compliance may be required which goes above and beyond these options. Conversely, the options proposed may go above and beyond existing regulations.

Wells, test holes	*W1*	-	*proper sealing with bentonite*
Foundation Piles	*F1*	-	*proper sealing of holes and piles*
Monitoring	*M1*	-	*implement appropriate monitoring*

3.3 Aquifer Protection through Land Use Controls

It has been established that various land use activities pose concern for aquifer protection. Further, it appears that through available technology and engineering design some degree of aquifer protection can be achieved. Combining these two aspects should make it possible to develop land use controls which would provide a reasonable degree of aquifer protection in each sensitivity zone established in Chapter 2. A prudent rationale for such controls would be the following:

- *to apply mitigative measures using common and established technology wherever possible;*
- *to avoid development of those activates which even with mitigative measures pose significant threat to the aquifers; and,*
- *to verify aquifer sensitivity through test drilling and hydrogeologic evaluation in those areas where aquifer sensitivity is unknown and the land use proposed carries significant inherent risk.*

Using the above rationale, an attempt has been made to establish possible future land use controls for each of the four sensitivity zones, as well as for the zone of unknown sensitivity. The following were evaluated in a step by step basis:

- *common land use activities that should or should not be taking place in each zone;*

- *common risk sources for each land use; and, mitigative measures that can be applied.*

Tables I. to V. contain the results of this evaluation process. Where it was deemed that an activity poses too much risk to be adequately mitigated with common risk control measures, the words "not recommended" were entered. Where it was deemed that risk control measures could be applied to achieve a reasonable degree of aquifer protection, codes from section 3.2 were used to identify commonly related risk sources and appropriate risk control measures. No entries were made if an activity generally does not pose a significant risk in that particular sensitivity zone.

Consideration was also given to land uses which may already exist in a given zone. A separate column has been provided in the tables for this circumstance. For activities which can be reasonably mitigated, the same codes were entered as for future land use recommendations. For activities which should probably not be taking place, the code system was used to recommend appropriate remedial mitigation which would at least reduce the risk of contamination from these activities. For activities which may pose considerable risk to the aquifer even after mitigation, for example industrial chemical facilities, monitoring or monitoring with possible relocation was recommended. The table entry is "(M1, possibly relocate)" is the strongest of all recommendations, suggesting that some monitoring and investigative work should be undertaken immediately. For cemeteries and landfills which cannot be readily relocated, abandonment was recommended.

It should be recognized that the land use recommendations put forward in tables I to V are deemed appropriate measures for common risk sources, using common mitigative technology. It is possible, through diligent engineering, application of superior mitigative technology and rigorous consideration of hydrogeologic principles to reduce the environmental risk of most any land use activity. Hence, an activity which would normally not be deemed compatible with a particular aquifer sensitivity classification can possibly be made compatible through proper design criteria. This limitation implies that the tables are general recommendations

which in no way are intended to replace prudent and case specific engineering judgement. This may be of particular significance for activities which are of such economic benefit that the cost of superior mitigative measures can be justified.

In addition to limitations which exist with regard to the table recommendations, limitations also exist on the use of the tables if used in conjunction with the sensitivity maps in figures 4, 5 and 6. As stated in section 2 above, the maps show approximate extent of sensitivity zones. Site specific conditions may vary and test drilling may be required to more rigorously assess local conditions. It is therefore recommended that the tables I to V be used only for purposes of regional planning, cursory review, or preliminary assessment.

Lastly, it should be recognized that any form of land use control may have negative economic impact in a particular area by limiting the activities which are allowed to take place. Little information is available on the economic value of groundwater resources or the cost of replacing these resources with water from other sources. Similarly, it is difficult to assess the economic benefit of locating a particular activity in a certain location. It can be concluded that although the value of the groundwater is enormous (see Chapter 1), more study is required to evaluate the cost and benefit of protecting this resource. It is recommended that such study be given consideration in future aquifer management planning.

Table I. Recommended Land Use Controls for Areas where Aquifer Sensitivity is "Extreme".

Land Use	Related Activity	Recommendation (future land use)	Recommendation (existing land uses)
Industrial	General	not recommended	(A1,C1,E1,R1,S1,U1,F1,M1)
	Chemical	not recommended	(M1) possibly relocate
	Warehousing	not recommended	(A1,C1,E1,R1,S1,U1,F1,M1)
Urban	Residential	not recommended	(E1,L1,P1,R2,M1)
	Commercial	not recommended	(A1,C1,E1,R1,S1,U1,F1,M1)
	Park/Golf	(L1,M1)	(L1,M1)
	Cemetery	not recommended	abandon
Rural	Acreage	(C1,E1,R2,U1,W1)	(C1,E1,R2,U1,W1)
	Farm or Other Yard	(A2,C1,E1,R2,U1,W1)	(A2,C1,E1,R2,U1,W1)
	Intensive Livestock	not recommended	(R2,M1)
	Institution	(A2,C1,E1,R2,U1,W1,M1)	(A2,C1,E1,L1,R2,U1,W1,M1)
	Equipment Compound	not recommended	(A2,C1,E1,L1,R2,U1,W1,M1)
	Pesticide/fert. Retail	not recommended	(M1) possibly relocate
	Elevator / Commercial	not recommended	(C2,M1)
	Community Well Site	(W1,M1)	(W1,M1)
	Park/Golf	(L1)	(L1)
	Gravel Quarry	(A1,S1,M1)	(A1,S1,M1)
	Borrow Pit	(A1,S1)	(A1,S1)
Agricultural	Native Grassland	(L1)	(L1)
	Pasture	(L1)	(L1)
	Dry-land Farming	(L1)	(L1)
	Irrigated Land	not recommended	(L2,M1)
	Effluent Irrigated	not recommended	(L2,M1)
Transportation	Highway	(R2,S1,W1,M1,F1)	(R2,S1,W1,M1,F1)
	Railway	(R2,S1,W1,M1,F1)	(R2,S1,W1,M1,F1)
	Gas pipeline	(E1,S1)	(E1,S1)
	Oil pipeline	not recommended	(E1,S1,M1)
	Airport	not recommended	(M1) possibly relocate
	Rail Yard	not recommended	(M1) possibly relocate
Waste Management	Landfill	not recommended	cover and abandon
	Sewage Lagoon	not recommended	(I1,M1)
	Containment Pond	not recommended	(I1,M1)
	Storm Pond	not recommended	(I1,M1)
	Private Sewage	(P1)	(P1)

Table II. Recommended Land Use Controls for Areas where Aquifer Sensitivity is "High".

Land Use	Related Activity	Recommendation (future land use)	Recommendation (existing land uses)
Industrial	General	not recommended	(A2,C1,E1,R1,S1,U1,M1)
	Chemical	not recommended	(A1,C1,E1,R1,S1,U1,M1)
	Warehousing	not recommended	(A2,C1,E1,R1,S1,U1,M1)
Urban	Residential	(E1,R2)	(E1,R2)
	Commercial	(A1,C1,E1,R1,S1,U1,M1)	(A1,C1,E1,R1,S1,U1,M1)
	Park/Golf	(L2)	(L2)
	Cemetery	not recommended	(E1,M1)
Rural	Acreage	(C2,E1,R2,U1,W1)	(C2,E1,R2,U1,W1)
	Farm or Other Yard	(C2,E1,R2,U1,W1)	(C1,E1,R2,U1,W1)
	Intensive Livestock	not recommended	(R2,M1)
	Institution	(C2,E1,R2,U1,W1)	(C2,E1,R2,U1,W1)
	Equipment Compound	(C2,E1,R2,U1,W1,M1)	(C2,E1,R2,U1,W1,M1)
	Pesticide/fert. Retail	not recommended	(A2,R2,M1)
	Elevator / Commercial	(C2)	(C2)
	Community Well Site	(W1,M1)	(W1,M1)
	Park/Golf	(L2)	(L2)
	Gravel Quarry	(S1,M1)	(S1,M1)
	Borrow Pit	(S1)	(S1)
Agricultural	Native Grassland	(L2)	(L2)
	Pasture	(L2)	(L2)
	Dry-land Farming	(L2)	(L2)
	Irrigated Land	(L2)	(L2)
	Effluent Irrigated	not recommended	(L2,M1)
Transportation	Highway	(R2,S1,W1)	(R2,S1,W1)
	Railway	(R2,S1,W1)	(R2,S1,W1)
	Gas pipeline	(E1,S1)	(E1,S1)
	Oil pipeline	(S1,M1)	(S1,M1)
	Airport	(S1,C2,M1)	(S1,C1,M1)
	Rail Yard	not recommended	(A2,C2,E1,R1,S1,U1,M1)
Waste Management	Landfill	(I1,M1)	(I1,M1)
	Sewage Lagoon	(I1,M1)	(I1,M1)
	Containment Pond	not recommended	(I1,M1)
	Storm Pond	(I1,M1)	(I1,M1)
	Private Sewage	(P2)	(P2)

Table III. Recommended Land Use Controls for Areas where Aquifer Sensitivity is "Moderate".

Land Use	Related Activity	Recommendation (future land use)	Recommendation (existing land uses)
Industrial	General	(C2,E1,R2,U2,M1)	(C2,E1,R2,U2,M1)
	Chemical	(C2,E1,R2,U2,M1)	(C2,E1,R2,U2,M1)
	Warehousing	(C2,E1,R2,U2)	(C2,E1,R2,U2)
Urban	Residential	(E1,R2)	(E1,R2)
	Commercial	(C2,E1,R2,U2)	(C2,E1,R2,U2)
	Park/Golf		
	Cemetery		
Rural	Acreage	(E2,R2,U1,W1)	(E2,R2,U1,W1)
	Farm or Other Yard	(E2,R2,U1,W1)	(E2,R2,U1,W1)
	Intensive Livestock	(R2)	(R2)
	Institution	(C2,E2,R2,U1,W1)	(C2,E2,R2,U1,W1)
	Equipment Compound	(C2,E2,R2,U1,W1)	(C2,E2,R2,U1,W1)
	Pesticide/fert. Retail	(A2,R2)	(A2,R2)
	Elevator / Commercial	(R2)	(R2)
	Community Well Site	(W1)	(W1)
	Park/Golf		
	Gravel Quarry		
	Borrow Pit		
Agricultural	Native Grassland		
	Pasture		
	Dry-land Farming		
	Irrigated Land		
	Effluent Irrigated		
Transportation	Highway	(R2)	(R2)
	Railway	(R2)	(R2)
	Gas pipeline		
	Oil pipeline	(S1)	(S1)
	Airport	(C2,M1)	(C2,M1)
	Rail Yard	(A2,C2,E2,R2,U2,M1)	(A2,C2,E2,R2,U2,M1)
Waste Management	Landfill	(I2)	(I2)
	Sewage Lagoon	(I2,M1)	(I2,M1)
	Containment Pond	(I1,M1)	(I1,M1)
	Storm Pond	(I2)	(I2)
	Private Sewage		

Table IV. Recommended Land Use Controls for Areas where Aquifer Sensitivity is "Low".

Land Use	Related Activity	Recommendation (future land use)	Recommendation (existing land uses)
Industrial	General	(E1,U2)	(E1,U2)
	Chemical	(E1,U2)	(E1,U2)
	Warehousing	(E1,U2)	(E1,U2)
Urban	Residential Commercial Park/Golf Cemetery	(U2)	(U2)
Rural	Acreage	(U1,W1)	(U1,W1)
	Farm or Other Yard	(U1,W1)	(U1,W1)
	Intensive Livestock		
	Institution	(U1,W1)	(U1,W1)
	Equipment Compound	(U1,W1)	(U1,W1)
	Pesticide/fert. Retail Elevator / Commercial Community Well Site Park/Golf Gravel Quarry Borrow Pit	(W1)	(W1)
Agricultural	Native Grassland Pasture Dry-land Farming Irrigated Land Effluent Irrigated		
Transportation	Highway Railway Gas pipeline Oil pipeline Airport Rail Yard		
Waste Management	Landfill Sewage Lagoon Containment Pond Storm Pond Private Sewage	(I2)	(I2)

Table V. Recommended Land Use Controls for Areas where Aquifer Sensitivity is "Unknown".

Land Use	Related Activity	Recommendation (future land use)	Recommendation (existing land uses)
Industrial	General	verify sensitivity	verify sensitivity
	Chemical	verify sensitivity	verify sensitivity
	Warehousing	verify sensitivity	verify sensitivity
Urban	Residential		
	Commercial	verify sensitivity	verify sensitivity
	Park/Golf		
	Cemetery		
Rural	Acreage	(U1,W1)	(U1,W1)
	Farm or Other Yard	(U1,W1)	(U1,W1)
	Intensive Livestock	verify sensitivity	verify sensitivity
	Institution	verify sensitivity	verify sensitivity
	Equipment Compound	verify sensitivity	verify sensitivity
	Pesticide/fert. Retail	verify sensitivity	verify sensitivity
	Elevator / Commercial	verity sensitivity	verity sensitivity
	Community Well Site	(W1)	(W1)
	Park/Golf		
	Gravel Quarry		
	Borrow Pit		
Agricultural	Native Grassland		
	Pasture		
	Dry-land Farming		
	Irrigated Land		
	Effluent Irrigated		
Transportation	Highway		
	Railway		
	Gas pipeline		
	Oil pipeline		
	Airport	verify sensitivity	verify sensitivity
	Rail Yard	verify sensitivity	verify sensitivity
Waste Management	Landfill	verify sensitivity	verify sensitivity
	Sewage Lagoon	verify sensitivity	verify sensitivity
	Containment Pond	verify sensitivity	verify sensitivity
	Storm Pond	verify sensitivity	verify sensitivity
	Private Sewage		

4.0 Review of Control Mechanisms

Earlier in this report, areas sensitive to aquifer contamination were delineated and guidelines for aquifer protection through land use controls were put forward. It remains to assess the degree to which existing legislation and municipal controls currently provide for aquifer protection, and to recommend options for improving such regulations if necessary. This section addresses these outstanding issues.

4.1 Saskatchewan Legislation[3]

Saskatchewan has a wealth of legislation relating, directly or indirectly, to the protection of aquifers. For the purpose of this study, legislation was grouped into three categories:

- *Legislation Relating to Information Gathering*
- *Legislation Relating to Environmental Control*
- *Legislation Relating to Land Use.*

[3] Abbreviations have been used throughout the text to identify Saskatchewan Environment and Public Safety, Saskatchewan Water Corporation, and Saskatchewan Energy and Mines. They are SEPS, Sask Water, and SEM respectively.

4.1.1 Information Gathering Legislation

Information gathering is an important aspect of aquifer protection in that it provides the baseline knowledge on which protective measures can be developed. Provincial groundwater information gathering includes collection of test hole and water chemistry data, mapping of geology as well as conducting aquifer studies. The following is a summary of relevant acts, the activities which are controlled, and a brief explanation of the purpose of each.

Act and Regulations	Activity Controlled	Explanation
The Ground Water Conservation Act (Sask Water)	Drilling Records	Legislation requires that all registered water well drillers submit drilling reports.
		Sask Water purchases E-logs for domestic and municipal wells.
		Sask Research Council maintains drilling records for research purposes.
	Chemistry Records	SEPS maintains copies of all chemical analyses that are provided.
		Sask Research Council maintains chemistry records for research purposes.
	Groundwater Reports	SEPS maintains a library of ground water reports that may be used for such things as environmental impact statements, licenses industrial and/or municipal waste water works, spill events, etc.
	Groundwater Reports	Sask Water requires the submission of ground water reports for all municipal and industrial uses of ground water before an approval to operate and the right to use ground water is issued.
		Sask Research Council has a library of ground water reports to be used for research purposes.

Geological Definition	Sask Research Council develops and prepares hydrogeological maps, cross-sections and reports.
Aquifer Evaluation	Sask Research Council may undertake aquifer evaluations for agencies under contract.
Reporting	Sask Water provides formal mapping and ongoing programs to develop hydrogeological cross-sections using CAD, maintains potentiometric maps, and reports and identifies flowing artesian wells. Sask Research Council develops and prepares hydrogeological maps and cross-sections.
Aquifer Allocation Plan	In 1959, the province initiated the registration of water well drilling equipment requiring drillers to file drillers reports on every well or test hole completed, the purpose of which was to create a ground water data base. In 1966, The Ground Water Conservation Act and Regulations were passed for the licensing of ground water use. In accordance with the Act, logs of wells drilled and information on the formation and materials encountered during drilling operations is submitted to Sask Water.
Aquifer Allocation Enforcement	Anyone contemplating the use of ground water must first obtain a ground water investigation permit and conduct a ground water investigation. The development of a well (except for domestic uses) requires an approval to construct, an approval to operate, and right to use ground water. Most approvals contain terms and conditions under which a proponent can operate. Anyone contravening the legislation or terms and conditions of an approval are subject to penalties under The Water Corporation Act.
Aquifer Allocation Documentation	Sask Water maintains a computer data base of all approved users, and of hydrogeological data on the developed wells.

		Sask Water maintains 90,000 well records on domestic wells. Industrial and municipal users are required to submit consumptive use data on an annual basis.
The Environmental Management and Protection Act (SEPS)	Data Base & Manual & EDP	SEPS maintains a water quality data base for the province (Enquadat). A water microcomputer data base for ground water is being implemented. Sask Research Council maintains a data base (paper, microfiche and electronic) on aquifer inventory items a. to f. inclusive.
	Water Chemistry Monitoring By User (project)	Monitoring includes drinking water. SEPS has developed a ground water monitoring protocol document for use by all agencies and clientele involved in ground water monitoring. The purpose of this document is to standardize data collection and report procedures.
	Water Chemistry Monitoring By Province (project)	Monitoring includes drinking water. SEPS has developed a ground water monitoring protocol document for use by all agencies and clientele involved in ground water monitoring. The purpose of this document is to standardize data collection and report procedures.
The Water Corporation Act (Sask Water)	Aquifer Allocation Procedure	Issues ground water investigation permits. Issues approvals for construction and operation and right to use ground water for all uses except domestic uses. Approvals usually contain terms and conditions with respect to operation, use and monitoring, etc.
	Monitoring	Sask Research Council undertakes monitoring of water levels and chemistry at various scales. This work is done to satisfy a need for the information and is not done directly as a regulatory function. Most industrial and municipal projects have conditions included on the approval to operate and use ground water from Sask Water that requires monitoring of the producing well and any surrounding monitoring wells and/or piezometers.

In assessing the adequacy of current information gathering legislation, the following observations, conclusions and recommendations can be made:

- *The information gathering process inherently uses a purpose oriented approach. Each agency collects information for its particular needs only. As a result, some data gaps exist. For example, data collection on water and oil well drilling is required by regulations; data collection on geotechnical drilling is not.*

- *The scope of this study limited the consultant's ability to identify all data gaps. Other studies, however, have reached similar conclusions. In 1986, McDonald conducted a study entitled "Saskatchewan Groundwater Quality Data Base Study". It was concluded that the various water quality data bases are incompatible and that initiatives are required to facilitate improved data gathering and data exchange.*

- *In light of the data gaps and potential data incompatibilities, further study should be conducted to:*

  - *identify data not being collected;*
  - *review how the data is stored, and how effectively it can be retrieved or utilized;*
  - *assess the compatibility of the various data bases now in place; and,*
  - *recommend improvements in the data gathering process and the data base structure.*

4.1.2 Environmental Legislation

Various provincial legislation affects environmental control. In principle, legislation pertains to industry or activity sectors such as the Pollution (by Livestock) Control Act or The Public Health Act. Activity sectors not addressed in specific acts fall under the general auspices of The Environmental Management and Protection Act. The following is a summary of relevant acts, the activities which are controlled by the acts, and a brief explanation of the purpose of each act.

Act and Regulations	Activity Controlled	Explanation
The Pest Control Products (Saskatchewan) Act (Agriculture and Food)	*Aerial Spraying of Pesticides Fertilizer*	*Act ensures users are protected, informed, and effectively apply pesticides. Control measures include: permits, licenses, examination, storage, inspection and monitoring.*
	Ground Spraying of Pesticides Fertilizers	*Act ensures users are protected, informed, and effectively apply pesticides. Control measures include: permits, licenses, examination, storage, inspection and monitoring.*
	Agricultural Chemicals (pesticides and fertilizers)	*Act ensures users are protected, informed, and effectively apply pesticides. Control measures include: permits, licenses, examination, storage, inspection and monitoring.*
The Pollution (By Livestock) Control Act 1984 (Agriculture and Food)	*Intensive Livestock Enterprises (feed lots)*	*Act controls the operation and relocation of factilities.*
	Livestock Manure Disposal	*Act controls the operation and relocation of factilities.*
The Dangerous Goods Transportation Act (Highways and Transportation)	*Spill from Transport Vehicles*	*Act applies to time that vehicles are on public highways (travelling). Dangerous goods manifest systems in place can react to incidents rapidly. Manifests are required by SEPS.*
The Mineral Resources Act, 1985 (SEM)	*Geophysical Boreholes*	*Act controls drilling and abandonment of geophysical shot holes.*
The Public Heath Act (Sask Health)	*Sanitation*	*Act controls location of feed lots so that drainage therefrom will not pollute any municipal or private water supply.*
	Cesspools	*Act requires private sewage disposal systems to be permitted through Sask Health.*
	Liquid Storage Structures (lagoons)	*Sask Health is involved in sewage lagoon systems that receive less than 4000 gallons of waste per day.*
	Septic Tanks	*Act requires private sewage disposal systems to be permitted through Sask Health.*
	Holding Tanks	*All holding tanks require a permit from Sask Health.*

The Environmental Management and Protection Act (SEPS)	*Ground Spraying of Effluent*	*SEPS issues permits for the application of waste water for irrigation.*
	Spill from Surface Storage	*Act requires reporting, clean up, and monitoring of spills.*
	Storage Tanks for Gasoline, Fertilizer, etc.	*SEPS requires (by licence) that all storage tanks of reagents or fuel be in a lined dyke area.*
		SEPS requires (by licence) that all waste water storage and treatment ponds be free from seepage.
		Design, application and operation guidelines for land use exist. Some types of operations are exempt from The Environmental Management and Protection Act.
	Liquid Spill Containment Structures (dyked retention areas)	*Some spill control structures are required at industrial effluent facilities that are licensed under The Environmental Management and Protection Act.*
		Mines Pollution Control Branch requires (by licence) that all storage tanks of reagents or fuel be in a lined dyke area.
	Tailings Management Areas	*SEPS issues licenses to construct and operate.*
		Act requires containment monitoring, effluent treatment and reclamation (long term stabilization).
	Sewage Sludge	*Construction and operation approvals are required by the Act*
	Open Pit Quarries	*Act requires control, handling and treatment of water (where necessary ground water monitoring is required). Reclamation is required.*
	Underground Mine Workings	*Act requires control, handling and treatment of water (where necessary ground water monitoring is required). Reclamation is required.*
	Solution Mining (production, maintenance and potash mining)	*Act requires control, handling and treatment of water (where necessary ground water monitoring is required) Reclamation is required.*
	Pipelines and Lift Stations	*Act outlines requirements for sewage pipes and lift stations.*

The Water Corporation Act (Sask Water)	*Water Works*	*Sask Water issues approvals to construct and operate works.*
	Water Well (production, injection, unused)	*Sask Water issues approvals to construct and operate producing water wells.*
	Canals, Locks, etc.	*Sask Water issues approvals to construct and operate canals, ditches, pipelines and other water conveyance works.*
	Drainage Wells (surface Water)	*Sask Water issues approvals to construct and operate drainage works (wells).*
The Oil & Gas Conservation Act (SEM)	*Spill Control*	*Act controls oil and salt water spills.*
	Road Application of Wastes	*SEM approval is required prior to disposal of wastes.*
	Land Application of Waste Drilling Fluids	*Guidelines apply to freshwater mud systems only.*
	Mineral Wells and Test Holes	*Act provides for emergency storage of salt water in lined pits. Brine pits at liquid propane gas storage facilities fall under the Act.*
	Oily Wastes	*Act provides for temporary storage of oily wastes and oil and salt water spill materials.*
	Water Wells	*Water source wells for oil field use and water injection wells are covered under the Act.*
	Oil and Gas Wells	*Casing and cementing programs to protect ground water are specified in the Act.*
	Oil and Gas (production, injection, unused)	*Water source wells for oil field use and water injection wells are covered under the Act.*
	Mineral Exploration Borehole	*Casing and cementing programs to protect ground water are specified in the Act.*
	Waste Disposal Well (injection, unused)	*Salt water disposal wells and other waste disposal wells are covered under the Act.*
	Pipelines and Tunnels	*SEM has responsibility for seeing that pipeline spills are cleaned up.*
	Liquid Propane Gas and	*SEM approval is required Natural Gas Caverns develop and operate storage projects.*
Environmental Assessment Act. (SEPS)	*"Developments" as defined under the Act*	*SEPS requires the completion of environmental impact assessments for all "developments" proposed in the province. Conditions for approval can relate to aquifer protection.*

In assessing the adequacy of current environmental legislation, the following observations, conclusions and recommendations can be made:

- *Some activities which could potentially cause aquifer contamination are excluded from the legislation. Broad legislation exists through the Environmental Management and Protection Act but no specific regulations exist. Road salting, airplane de-icing, equipment washing, and foundation piles are examples. Future legislation should be expand to include such activities, and to provide broadly applicable controls. An in-depth review of common activities currently not controlled should be conducted.*

- *Specific controls relating to the protection of the overburden above aquifers do not exist. For example, there are no controls on land stripping, excavating, ditching and trenching; sealing of wells and test holes; or, drilling of geotechnical bore holes and piles. Controls of this type would provide better protection of aquifers through overburden preservation and should be considered in future legislation.*

- *Existing environmental legislation is mitigation oriented and the onus is often placed on project proponents to justify the adequacy of mitigative measures. Thus, the quality of mitigation can vary widely and some mitigation may be less effective than others. It would be beneficial to establish standards or guidelines for common types of land use activities. This would provide more consistency in mitigative measures. Wherever possible, guidelines should address specific criteria for aquifer protection.*

- *Existing legislation is not cognizant of the differences in aquifer sensitivity which may exist from one location to the next. Site specific sensitivity is important as it affects the level of mitigation required, and the suitability of a site for certain activities. Future legislation and environmental controls should reflect the additional mitigative efforts which may be required in sensitive areas.*

- *For industrial project development indirect control is exercised through the review process of The Environmental Assessment Act. Control over other aspects of environmental control is exercised through a number of different acts covering various issues. Environmental legislation dealing directly with aquifer protection does not exist. It would be beneficial to enact legislation specifically dealing with protection of aquifers. This would facilitate dealing with aquifer protection in a simple and efficient manner.*

4.1.3 Land Use Legislation

The Planning and Development Act provides urban and rural municipalities with a mechanism by which to adopt statutory policy plans, referred to as development plans or basic planning statements. These must be implemented by zoning bylaws and approved by either the Minister of Rural Development or the Minister of Urban Affairs. This process assures that the province reviews local policy and provides direction for revisions as necessary. Implicitly, aquifer protection guidelines adopted by government over time could be drawn on in the review of statutory plans or amendments; thereby, effecting land use control over land sensitive to aquifer contamination.

In the case of subdivision planning, a standard referral system exists during which agencies of interest are contacted and all regulatory requirements are identified. Aquifer protection measures could be identified during this process by Saskatchewan Environment and Public Safety or other agencies involved.

Under Section 13, the Act provides for the establishment of provincial land use policies, which are to be considered in the preparation and review of any statutory plan or zoning bylaw. However, no such policies have been established to date.

Section 131 of The Urban Municipality Act, 1984, allows any urban municipality to prohibit "the carrying on of any class of business that the council considers liable to become or give rise to a nuisance". This clause can be used to restrict the development of certain land use activities and is especially useful for municipalities which have no statutory plan or zoning bylaw and are located in sensitive areas.

Section 144 of the Act makes provisions for urban municipalities to protect water resources in their area of jurisdiction. To date, no use has been made of this provision.

In assessing the provincial land use legislation and its current ability to affect aquifer protection, the following observations and conclusions can be drawn:

- *The Planning and Development Act as well as The Urban Municipalities Act make provisions for municipalities to effect land use and protection of water resources. Review and testing of these provisions would be required to assess how effectively they could be used to protect the aquifers.*

- *The Planning and Development Act allows provincial authorities to review local policy and provide direction as necessary. It is recommended that the province considers using this legislation to control land use policy and activity over the aquifers. Further work would be required to evaluate how this could be done most effectively.*

4.2 Municipal Land Use Controls

It is apparent from the land use legislation that municipal governments have substantial influence over land use activity in their area of jurisdiction. In this section of the report, by-laws and initiatives by selected municipal governments have been examined to determine if and how this is currently being done. Discussed below are the City of Regina, and the rural municipalities of Edenwold, Lumsden, Pense and Sherwood.

4.2.1 City of Regina

The City of Regina has several controls which relate directly or indirectly to aquifer protection. Significant controls include the Regina Zoning Bylaw #8484, the refuse disposal and anti-litter bylaw, the traffic bylaw as it relates to dangerous goods transport, the Environmental Engineering section, and various miscellaneous environmental initiatives. Also, the City has several sections in the Regina

Subdivision Bylaw #7148 that could be used to restrict the size and number of subdivisions in a sensitive area. This could have an indirect effect on restricting the number of individual property owners and businesses.

The purpose of the Regina Zoning Bylaw #8484 is to control land use; and, to provide for the amenity of the area, and for the health, safety, and general welfare of the inhabitants of the city. The existing zoning bylaw contains no direct references to aquifer protection, however it is under active review. Some indirect control is achieved by:

- *designating land sectors as either residential, commercial or industrial zones.*
- *requiring all residential and commercial development to undergo a permit process.*
- *requiring industrial development to undergo a review process.*

The review process can deem an industrial land use to be hazardous, requiring a "discretionary use permit". The permit process for discretionary use consists of soliciting comments from various city departments and possibly government agencies. Where concerns about aquifer protection are identified, mitigative measures can be required in the development permit.

The purpose of the traffic bylaw is to assure public safety as it relates to vehicle travel. The transportation of dangerous goods is restricted to designated routes which allow ready access in the event of a spill accident. At this time, aquifer protection is not taken into account in the selection of dangerous goods routes.

The refuse disposal and anti-litter bylaw regulates removal of wastes to the City's sanitary landfill. The bylaw can be seen as an indirect aquifer protection measure in that waste disposal is restricted to approved and designated sites only. Consideration of aquifer protection in the site selection process can form an indirect protection measure.

The purpose of the Environmental Engineering section is to provide environmental expertise to other departments, and to conduct environmental assessment and monitoring. Current functions of the department include the following (personal communications with Mr. G. Niemenen):

- *conduct monitoring in compliance with provincial requirements on landfills, sewage lagoons, and water works.*
- *review discretionary use applications, or other development matters as may be requested by other departments.*
- *provide assistance in spill control.*
- *conduct waste management studies.*
- *conduct hazardous waste screening as it relates to sewage and landfill uses.*

Miscellaneous environmental initiatives by the City demonstrate increasing concern about aquifer protection. Examples include the following:

- *aquifer sensitivity mapping (Lissey, 1981) conducted by the Municipal Engineering Department;*
- *consideration given to aquifer protection in the "Rail Relocation Study, (Hardy, 1978), the "Land Use Study" (City of Regina, 1989), and the "Waste Management Study" (City of Regina, 1989);*
- *preparation of "Draft Location Criteria for Hazardous Waste Operations in and around the City of Regina" (City of Regina, 1989) which includes restrictions for locating over the aquifer; and,*
- *participation on the "Regina Groundwater Technical Committee" and co-funding of related aquifer management studies.*

Absent in the City's controls on aquifer protection is a direct integration with the land use planning process. The City appears to be taking steps towards such integration with a recently published study entitled "Industrial Zoning Review - Environmental Control Considerations (McDonald, 1989)". The study was

commissioned to assess the adequacy of current environmental controls including aquifer protection. The report has been tabled with Regina City Council and is currently in public circulation for comment. It is proposed that the report will serve as a basis for an amendment to the Regina Zoning Bylaw to better control industrial land use over portions of the Regina area aquifers which lie within the city limits.

4.2.2 R.M. of Edenwold

The R.M. of Edenwold recently undertook a review of the existing bylaws in the mid 1980's. The review resulted in enactment of Bylaw No. 1987-43 (Development Plan). The development plan addresses concerns on land use, subdivision and protection of water supplies. The following are relevant stipulations reprinted from the plan:

> page 29, "High density residential development shall be primarily serviced with central water and sewage facilities";
>
> page 51, "Council may require developers to provide professional certified, resource management, environmental, geo-technical and hydrological reports for lands which are deemed by Council to be environmentally sensitive";
>
> page 52, "The R.M. Council shall encourage and required adequate surface water drainage throughout the R.M. and new development sites to avoid flooding, erosions and pollution";
>
> page 58, "Council shall cooperate with the Saskatchewan Water Corporation, Saskatchewan Environment and Public Safety, and Saskatchewan Health to ensure that domestic, commercial and industrial water supplies are properly managed and do not become polluted or depleted".

The plan is significant in that it is the earliest development plan (1987) in the Regina area which makes reference to "environmentally sensitive" areas in terms of groundwater protection. It also sets precedent in that developers are deemed responsible for aquifer protection and will undergo the scrutiny of independent hydrogeologic assessment and review by Council.

4.2.3 R.M. of Lumsden

The R.M. of Lumsden is currently in the process of introducing new bylaws and a development plan. The draft bylaw and development plan for the municipality addresses numerous controls and stipulations which pertain to aquifer protection. Controls include direct measures such as requiring minimal impacts due to development on the aquifer, and indirect controls such as use of sewage facilities. The following excerpts have been reprinted from the Draft Development Plan:

"PART III. DEVELOPMENT ISSUES - 1. Development Issues, (viii) Environmentally Sensitive Lands

Environmentally sensitive lands, which involve unstable Valley slopes, surface and groundwater supplies, a high water able, flooding and wind erosion, must be managed to achieve effective resource management, development suitability, low maintenance, efficient servicing and public safety."

PART V. RURAL DEVELOPMENT AND DISTRICT - 3. Policies, (5) Resource Management

Agricultural and all other development and subdivisions shall be subject to the plan policies regarding:

(i) environmentally sensitive lands,
(ij) critical wildlife habitats,
(iii) mineral resource extraction,
(iv) heritage resource management, and
(v) flood hazard lands.

PART VI. VALLEY DEVELOPMENT AND DISTRICT - 3. Policies, (7) Resource Management

All development and subdivisions within the Valley Development District shall be subject to the plan policies regarding:

(i) flood hazard lands,
(ii) unstable slopes,
(iii) environmentally sensitive lands,
(iv) critical wildlife habitat,
(v) mineral extraction
(vi) heritage resource management, and
(vii) annexation.

PART VII. RESIDENTIAL DEVELOPMENT POLICIES - 2. Policies

(2) Low Density Residential Development (iii) Development Criteria

(c) minimize groundwater and water supply, pollution and overuse,

(3) Medium Density Residential Development (iii) Development Criteria

(b) minimize groundwater and water supply pollution and overuse,

(3) Medium Density Residential Development (v) Information

(d) Hydrological - water supplies, aquifer testing, flooding, pollution prevention, etc.,

Similar policies are contained in:

PART VIII. TOURISM AND RECREATION DEVELOPMENT - 2. Policies

PART IX. COMMERCIAL DEVELOPMENT - 2. Policies

PART X. LIGHT INDUSTRIAL DEVELOPMENT - 1. Objectives

PART X. LIGHT INDUSTRIAL DEVELOPMENT - 2. Policies

PART XI. MINERAL EXTRACTION DEVELOPMENT - 2. Policies

PART XII. CRITICAL WILDLIFE RESOURCE DEVELOPMENT - 2. Policies

PART XIV. ENVIRONMENTAL MANAGEMENT 1. Objectives

(4) To protect groundwater supplies from overuse and pollution.

PART XIV. ENVIRONMENTAL MANAGEMENT 2. Policies

(1) Environmentally Sensitive Lands (i) Definition

(c) groundwater supplies,
(h) aquifer recharge capability
(m) lands sensitive to aquifer pollution and rapid vegetative destruction.

PART XIV. ENVIRONMENTAL MANAGEMENT 3. Development Priority

(i) Council shall ensure that the type, form, scale and density of development and subdivision is compatible with the physical opportunities and limitations of the site.

(ii) Council shall not be required to rezone land, permit development, or to recommend subdivision approval for environmentally sensitive lands, where plan and zoning bylaw requirements are not met.

PART XIV. ENVIRONMENTAL MANAGEMENT 7. Groundwater

(i) General

(a) Development shall not deplete or pollute groundwater resources within the rural municipality.

(b) Council shall co-operate with the Saskatchewan Water Corporation, Agriculture and Food, Environmental and Public Safety, Health, and adjacent municipalities in this regard.

(ii) Groundwater Supplies

Groundwater supplies and aquifer recharge areas shall be managed to avoid overuse and pollution. Council may prohibit development in such areas.

PART XV. MUNICIPAL SERVICES AND PUBLIC UTILITY MANAGEMENT"

Restrictions on waste disposal areas are mentioned with regard to compliance with Provincial Regulations.

The bylaw, being developed concurrently reflects and complements the objectives of the development plan. The following excerpts were identified in the Draft Zoning

ByLaw:

"PART IV. - GENERAL DEVELOPMENT STANDARDS, B. Environmental, 4. Groundwater

(i) Protection

(iii) potential contamination of the aquifer.

PART IV. - GENERAL DEVELOPMENT STANDARDS, B. Environmental, 5. Water Disposal

(1) General

All liquid, solid and gaseous wastes and all toxic and hazardous substances shall be disposed, handled, transported and managed according to federal, provincial and municipal requirements.

PART IV. - GENERAL DEVELOPMENT STANDARDS, C. Services and Public Utilities, 7. Developer Responsibilities

(iv) environmental concerns, including groundwater, surface water, water supplies, public safety, nuisance mitigation measures, monitoring, etc., and".

Characteristic of the development plan is the reliance on a third party to provide independent assessments on the impact development will have on an area. The project proponent can obtain such assessments from engineering consultants who may recommend mitigative measures for a project. Preparation of protection guidelines may be necessary to achieve uniformity of mitigation over sensitive lands.

Rural Development representatives indicate that significant local concern has been expressed regarding the identification of environmentally sensitive areas and the establishment of related management policies and regulations in proposed municipal planning bylaws. The general concern is the negative impact which these provisions may have on property values, viability of agricultural operations and future economic diversification. As a result of these and other concerns, the R.M. council is presently giving further consideration to the bylaws (personal communications).

4.2.4 R.M. of Pense

The R.M. of Pense does currently not have a development plan which considers protection of environmentally sensitive areas. Only two general provisions in Zoning Bylaw No. 5-79 relate to environmental protection. These have been reprinted from the bylaw as follows:

- page 9, "A copy of all approved Development Permit applications involving the installation of water and sanitary services shall be supplied to the local office of the Department of Public Health."
- page 11, " Subject to the Acts and Regulations administered by the Departments of Health and Environment no liquid, solid or gaseous wastes shall be allowed to be discharged into any stream, creek, river, lake, pond, slough, intermittent drainage channel or other body of water, onto any land or into the air."

The R.M. of Pense is planning a review of existing bylaws and preparation of a development plan in the coming years. Inclusion of various aquifer protection controls in the new plan and bylaws is expected (personal communications with administrator).

4.2.5 R.M. of Sherwood

The R.M. of Sherwood recently prepared a draft Development Plan for the Regina Planning District. The draft was prepared by City and R.M. staff but has not been advertised as required in The Planning and Development Act. It may undergo several more drafts before being formally submitted to the Minister of Rural Development for approval. The current draft includes direct reference to aquifer protection as a development planning issue. The relevant excerpts of the plan are:

"1. Issue: Groundwater Protection

Background

The Regina Planning District contains four underground water bodies or aquifers (Condie, Regina, Richardson, Zehner aquifers) which supply well water to rural residents and the City of Regina. Approximately 30% of the City's water supply is derived from The Regina Aquifer.

Contamination of this water supply could result in major expenditures for water treatment facilities and/or accessing alternative sources of water. The Condie Aquifer System is the "Most Sensitive" because it is the closest to the surface.

Water in the aquifers is replaced as rainfall seeps into the ground. This process is known as recharge. Certain areas over the aquifers are particularly important sources of recharge. These recharge areas are environmentally sensitive since pollutants can more easily seep into the aquifers where soil cover is reduced, or is of a more permeable nature (e.g. sand).

A well head protection zone is a concept that originated in the United States where it is used to regulate land uses (e.g. chemicals) in the vicinity of water wells to minimize the risk of pollution entering the aquifer through the well. There are 187 water wells in the Regina Planning District as identified by Saskatchewan Water Corporation.

Proposed Objectives

1) To ensure that development does not result in pollution of underground aquifers.

2) To ensure that ground water resources are not unnecessarily over utilized or depleted.

Proposed Policy Options

1) That growth of land uses over the four aquifers in the District be unrestricted.

2) That the development of land uses over the aquifers proceed with appropriate mitigative measures. Some examples of these mitigative measures are: drainage design, liners to contain spills, placing fuel tanks above ground instead of burying them, and requiring setbacks of development from known aquifer recharge areas.

3) That the development of certain uses over the aquifers be prohibited. For example, Council may wish to prohibit chemical processing, heavy industrial uses, fuel storage, chemical container disposal sites, landfill sites and other uses.

4) That a well head protection zone be created that would regulate land uses which have the potential to pollute the aquifers in the immediate vicinity of water wells.

5) That certain uses in the vicinity of aquifer recharge areas be restricted or prohibited. Some aquifer recharge areas are: gravel pits, Condie Nature Refuge, Wascana Creek, Boggy Creek, Pilot Butte Creek and Cottonwood Creek.

6) That the expansion of industrial uses that are heavy users of water be prohibited.

Throughout the development plan, the objectives on groundwater protection are reiterated in the discussion of various development issues including those relating to sand and gravel extraction, industrial development and commercial development.

Characteristic of the Sherwood development plan is an attempt to designate various areas over the aquifer, and specifically the Condie Aquifer, as environmentally sensitive. Maps are provided in the plan outlining the extent of the aquifers. The use of maps is beneficial in providing developers with a quick reference on spatially related concerns.

4.2.6 Other Municipalities

Detailed review of all municipal governments in the study area is beyond the scope of this report. However, cursory information has been provided by Urban Affairs on other urban municipalities in sensitive parts of the study area. These are the Village of White City, the Town of Pilot Butte and the Town of Lumsden. In summary this information states:

- *The Village of White City has a zoning bylaw which was approved in 1982. Because it was adopted prior to the current Planning and Development Act, the Council is not required to adopt a statutory plan which could include aquifer protection policy. Its zoning bylaw does have provisions to prohibit specified uses. This could be adapted to include aquifer protection standards and require more testing and other measures prior to issuance of development permits. As well, all heavy industrial uses are discretionary. This gives Council an extra degree of control over both the principle of development and the drafting of special regulations to ensure that environmentally safe development occurs on a site-specific basis. Improvements could be made to give Council wider regulatory powers.*

- *The Town of Pilot Butte had a new Basic Planning Statement and Zoning Bylaw approved by the Minister of Urban Affairs in 1989. The Basic Planning Statement contains very specific policies regarding aquifer protection in respect to industrial development. These policies could be expanded to apply to commercial, residential and public services uses. The implemented zoning bylaw could be improved by adding provisions for testing, special regulatory powers, etc., which are identified in the future.*

- *The Town of Lumsden has a Basic Planning Statement and Zoning Bylaw, both approved in 1988. These have extensive floodplain, drainage control, and slump hazard policies and regulations in them. While they are not specifically geared toward aquifer protection, they can be used to achieve that purpose. The zoning bylaw also has provisions regarding waste disposal and obnoxious uses, and will permit special regulations to be applied to discretionary uses. These provisions could also be improved and strengthened.*

4.2.7 Assessment of Municipal Controls

The review of municipal land use controls presented above allows for the following observations, conclusions and recommendations:

- *Significant variability exists among the various development plans and zoning bylaws currently in place at the municipal level. While aquifer protection is dealt with comprehensively in some jurisdictions, it is nearly absent in others. It is recommended that the province examine a means of providing more direction and greater consistency in the preparation of municipal controls affecting aquifer protection.*

- *Existing initiatives in various municipalities reflect a conscious effort by local councils to protect the aquifers. However, concern has also been raised over possible negative economic impact of not approving potentially rate paying activities. The result is an undesirable double objective at the municipal level. To insure objectivity in regards to land use developments over the aquifer, greater involvement by the province is recommended.*

4.3 Other Jurisdictions

To provide ideas for assessing or improving provincial controls on aquifer protection, a review has been conducted of groundwater management initiatives in other jurisdictions. Essentially two approaches appear to be prevalent:

- *direct implementation of Aquifer Protection Legislation which requires compliance from all levels and planning and development; or,*

- *indirect implementation by creating awareness of aquifer sensitivity and documenting development guidelines which can be used in the development review process.*

4.3.1 Direct Implementation

Examples of implementation through the direct approach are Colorado, California, and West Germany. The oldest and most established of the three is the German aquifer management and protection legislation which has been in place since 1959. Federal legislation stipulates that groundwater protection through well-head protection measures is mandatory in all states (provinces). Delineation and enforcement of well-head protection zones has been delegated to each state. In cases were a state resists its delegated function, the federal agencies can take over delineation and enforcement.

Although minor differences exist in the details of implementation, nearly all states in the German federation appear to follow the same approach. The state agencies have mapped and delineated well-head protection areas for virtually every municipal well field based on available geologic information. Protection areas have been divided into three zones. The immediate well head area which must be fenced and posted. A larger area of high risk, is mapped and posted. In this area no urban/industrial development nor transportation of hazardous goods is permitted. A fringe area is mapped in which some restrictions to urban and industrial developments apply.

To enforce the legislation in most areas, the state government further delegates authority to county and local government to control development in the well-head protection areas as required. Onus is placed on the well owner (community) to maintain fencing and posting of signs as required.

The well-head protection strategy with its well defined legislative structure is seen as an effective measure for protection of municipal production wells. However, some shortcomings exist in limiting aquifer protection to well-head areas. Protection does not apply to sensitive lands which are outside of the well-head areas. Indeed, numerous examples of nitrate contamination from agriculture and other pollution problems have been documented outside of well-head protection areas (personal communications with the government of North-Rhine Westphalia). With very few exceptions, households in West-Germany are connected to municipal

water supply systems. Effects on public health outside well-head protection areas is therefore of little concern. Also, due to abundance of surface and groundwater resources in West-Germany, several supply alternatives are usually available should a production area become contaminated.

In the Regina area, water supply options are limited and a large number of residences rely on private wells. Sensitivity mapping is therefore preferable to well-head protection. However, the West-German approach of integrating aquifer protection with zoning controls is directly applicable to the implementation of aquifer protection in the Regina area. The use of aquifer management and protection legislation should be considered a viable approach.

Direct aquifer protection measures consist of the following essential components:

- *Aquifer Management and Protection Legislation which enforces control standards and development restrictions;*
- *gaining knowledge of the physical setting of the aquifers and their sensitivity to contamination;*
- *delineation of lands over the aquifers into zones of varying sensitivity;*
- *mitigative land use development controls;*
- *mitigative remedial controls for existing land uses;*
- *monitoring to detect failure of mitigative measures.*

Protection of the aquifers is an ongoing process and requires implementation through permanent government program or an administrative body established through the Aquifer Management and Protection Legislation. The objective of such a program or body would be to manage and protect the aquifers. The Regina Groundwater Technical Committee has discussed the benefits of instituting an Aquifer Management Authority. The authority approach would assure independence from economic or political objectives which could otherwise interfere with protection of the aquifer; and, allow ongoing improvement on the state of knowledge of the aquifers.

4.3.2 Indirect Implementation

The indirect approach to aquifer protection has not been as well documented. In Manitoba attempts are under way to fence off an aquifer protection area near Winkler (personal communications with government of Manitoba). The purpose of the fencing project would be to raise public awareness of the sensitive area.

The Alberta government is contemplating groundwater sensitivity mapping on a regional basis. The purpose of this mapping would in part be intended to support new standards for underground storage tanks. Tanks in more sensitive areas will be required to adhere to more stringent design specifications (personal communications with government of Alberta).

Indirect aquifer protection measures take various forms but should consist of one or more of the following:

- *gaining knowledge of the physical setting of the aquifers and their sensitivity to contamination;*
- *delineation of lands over the aquifers into zones of varying sensitivity or risk of contamination;*
- *environmental control guidelines which reduce the risk of a given activity through mitigative technology, and which are cognizant of various levels of aquifer sensitivity;*
- *development guidelines which prevent activities over the aquifer whose environmental risk cannot be adequately mitigated through control standards, and which are cognizant of various levels of aquifer sensitivity;*
- *a public awareness program to promote voluntary compliance with protection guidelines;*
- *indirect implementation of control and development guidelines through the environmental review process associated with industrial and some types of urban activity.*
- *monitoring to detect failure of mitigative measure.*

The indirect approaches identified within the scope of this report deal with only one aspect of aquifer protection at a time. Encompassing all aspects of aquifer management and protection would have to involve various government agencies and municipal governments. Difficulties might also exist in policing and enforcing protection guidelines where they impact interjurisdictional boundaries.

4.3.3 Comparison of Approaches

Aquifer protection can take on a direct or an indirect approach. Of the two approaches presented, the direct approach is the preferred approach because:

- *it would provide the long term commitment required to protect the resource;*
- *it would include Aquifer Management and Protection Legislation encompassing all aspects of aquifer management and protection in one document;*
- *it would ensure consistency in mitigative measures applied in various municipal jurisdictions.*

The indirect approach is less attractive because:

- *it requires interjurisdictional collaboration at various levels to enforce all aspects of aquifer management and aquifer protection;*
- *no models exist for how an indirect approach could be comprehensively implemented;*
- *the absence of legislation may cause aquifer protection to be more influenced by prevailing economic and political objectives.*

Indirect aquifer protection measures through the use of guidelines should be seen as an intermediate step. It benefits from public support through awareness and provides a training ground for the development of appropriate measures. However, only aquifer protection legislation provides the long term commitment required to protect the resource.

5.0 Summary of Conclusions and Recommendations

This chapter summarizes the conclusions and recommendation which have been reached throughout the report. In keeping with the scope of the report, the summary has been separated into four parts to address the main objectives of the study, namely:

- *to map lands over the aquifers sensitive to contamination;*
- *to identify existing land use concerns;*
- *to evaluate possible aquifer protection measures for such lands; and,*
- *to evaluate existing legislation and control mechanisms related to land use and protection of aquifers.*

5.1 Mapping of Sensitive Lands over the Aquifers

The following points summarize the main conclusions and recommendations of Chapter 1 and 2 of this report:

1. A map has been compiled showing areas over the major aquifers in the Regina area which are sensitive to groundwater contamination. The map was created by integrating existing maps on "depth to aquifers" and "surficial geology". Lands have been categorized into five zones according to the following classification criteria:

Extreme - *a major aquifer is present which extends to surface and has no protective clay or till overburden; or, a major aquifer is present beneath 0 to 5 metres of undifferentiated overburden of which the upper portion consists of silty or sandy material.*

High - *a major aquifer is present beneath 0 to 5 metres of protective clay or till overburden; or, a major aquifer is present beneath 5 to 10 metres of undifferentiated overburden of which the upper potion consists of silty or sandy material; or, a major aquifer has not been mapped but surficial sands are present which may form local unconfined aquifers of limited extent.*

Moderate - *a major aquifer is present beneath 5 to 10 metres of protective clay or till overburden; or, a major aquifer is present beneath no less than 10 metres of undifferentiated overburden of which the upper portion consists of silty or sandy material.*

Low - *a major aquifer is present beneath no less than 10 metres of protective clay or till overburden.*

Unknown - *no major aquifers have been mapped and the surficial material is clay or till offering a protective cover of unknown thickness; minor aquifers may be present but have not been mapped; more test hole data and mapping is required to better assess the sensitivity of these areas; at most locations sensitivity is expected to be low.*

2. Restrictions apply to the use of the map for site specific needs. The existing maps used as source data, particularly the "depth to aquifers" maps, are based on available test hole data in the area, making them interpretive, approximate and regional in nature. These limitations carry into the Sensitivity Map produced and render it to be regional in nature, too. For site specific needs, the user is advised to refer back to the source maps and/or conduct test drilling at the site for verification of local conditions.

3. The Sensitivity Map differs from two earlier maps produced for parts of the study area. The first is by Lissey (1981) showing slightly different boundaries due to a slightly different classification criteria and older source data. The second is by McDonald (1989). The McDonald map is based only on "extent" and not "depth to" aquifer; and, it differs substantially from the current map.

5.2 Existing Land Use Concerns

The following points summarize the main conclusions and recommendations of Chapter 3 of this report:

1. An inventory of major land uses in the study area was conducted and documented on a map of Aquifer Sensitivity and Urban/Industrial Land Use. Areas of potential concern include:

   - *communities and urban land use located in extremely sensitive areas (Pilot Butte, White City and nearby subdivisions);*
   - *landfills lagoons and plant sites located on lands highly and extremely sensitive in various parts of the study area but particularly north and east of the City of Regina;*
   - *City of Regina industrial expansions favoured for a northerly and easterly trend onto lands zoned highly sensitive;*
   - *industrial activity on highly sensitive lands, particularly the North Regina Industrial Park;*
   - *proposed rail relocation onto highly sensitive lands north of Regina;*
   - *apparent urban, commercial and light industrial expansion trends over highly sensitive lands along Trans Canada Highway between the City of Regina and White City.*

5.3 Aquifer Protection

The following points summarize the main conclusions and recommendations of Chapter 3 of this report:

1. Various land uses pose concern for aquifer protection. These land uses include: industrial, urban, rural, agricultural, transportation or waste management land uses. Section 3.1 of this report summarizes common activities and concerns associated with them.

2. Some degree of risk reduction and aquifer protection can be achieved through the use of mitigative environmental technology. Common technology exist and can be applied to above ground storage tanks, chemical use, excavations, waste containment, land application of substances, sewage systems, runoff, spills, underground storage tanks, wells, test holes and foundation piles. Risk reduction can also be achieved through appropriate monitoring.

3. Awareness of land use concerns and knowledge of mitigative environmental technology form a basis for developing land use controls. Tables I to V in Section 3.3 of this report make recommendations on land use controls which can be applied to protect the aquifers for each of the five sensitivity classes developed in Chapter 2. The recommended controls constitute appropriate measures for common risk sources, using common mitigative technology. They may not apply where more case specific mitigative engineering is being carried out.

4. Recommended land use controls in Tables I to V can be used in combination with the Sensitivity Map for purposes of regional planning, cursory review or preliminary assessment. Due to the approximate and regional nature of the Sensitivity Map, combined use for site specific analysis is not recommended. For site specific uses it is recommended that local conditions are verified using test drilling to rate sensitivity according to the classification system in Chapter 2.

5. Any form of land use controls can have negative economic impact in a particular area. Conversely, having groundwater resources available in a particular area is of economic value. A study is required to assess the cost and benefit of protecting groundwater resources. It is recommended that such study be given consideration in future aquifer management planning.

5.4 Legislation and Control Mechanisms

The following points summarize the main conclusions and recommendations of Chapter 4 of this report:

1. Saskatchewan has a wealth of legislation relating, directly or indirectly, to the protection of aquifers. For the purpose of this study, legislation was grouped into three categories:

    - *Legislation Relating to Information Gathering*
    - *Legislation Relating to Environmental Control*
    - *Legislation Relating to Land Use.*

2. In assessing the adequacy of current information gathering legislation, the following observations, conclusions and recommendations can be made:

    - *The information gathering process inherently uses a purpose oriented approach. Each agency collects information for its particular needs only. As a result, some data gaps exist. For example, data collection on water and oil well drilling is required by regulations; data collection on geotechnical drilling is not.*

    - *The scope of this study limited the consultant's ability to identify all data gaps. Other studies, however, have reached similar conclusions. In 1986, McDonald conducted a study entitled "Saskatchewan Groundwater Quality Data Base Study". It was concluded that the various water quality data bases are incompatible and that initiatives are required to facilitate improved data gathering and data exchange.*

    - *In light of the data gaps and potential data incompatibilities, further study should be conducted to:*

        - *identify data not being collected;*
        - *review how the data is stored, and how effectively it can be retrieved or utilized;*
        - *assess the compatibility of the various data bases now in place; and,*
        - *recommend improvements in the data gathering process and the data base structure.*

3. In assessing the adequacy of current environmental legislation, the following observations, conclusions and recommendations can be made:

   - *Some activities which could potentially cause aquifer contamination are excluded from the legislation. Road salting, airplane de-icing, equipment washing, and foundation piles are examples. Future legislation should be expand to include such activities, and to provide broadly applicable controls. An in-depth review of common activities currently not controlled should be conducted.*

   - *Specific controls relating to the protection of the overburden above aquifers do not exist. For example, there are no controls on land stripping, excavating, ditching and trenching; sealing of wells and test holes; or, drilling of geotechnical bore holes and piles. Controls of this type would provide better protection of aquifers through overburden preservation and should be considered in future legislation.*

   - *Existing environmental legislation is mitigation oriented and the onus is often placed on project proponents to justify the adequacy of mitigative measures. Thus, the quality of mitigation can vary widely and some mitigation may be less effective than others. It would be beneficial to establish standards or guidelines for common types of land use activities. This would provide more consistency in mitigative measures. Wherever possible, guidelines should address specific criteria for aquifer protection.*

   - *Existing legislation is not cognizant of the differences in aquifer sensitivity which may exist from one location to the next. Site specific sensitivity is important as it affects the level of mitigation required, and the suitability of a site for certain activities. Future legislation and environmental controls should reflect the additional mitigative efforts which may be required in sensitive areas.*

   - *For industrial project development indirect control is exercised through the review process of <u>The Environmental Assessment Act</u>. Control over other aspects of environmental control is exercised through a number of different acts covering various issues. Environmental legislation dealing directly with aquifer protection does not exist. It would be beneficial to enact legislation specifically dealing with protection of aquifers. This would facilitate dealing with aquifer protection in a simple and efficient manner.*

4. In assessing the provincial land use legislation and its current ability to affect aquifer protection, the following observations and conclusions can be drawn:

   - *<u>The Planning and Development Act</u> as well as <u>The Urban Municipalities Act</u> make provisions for municipalities to effect land use and protection of water resources. Review and testing of these provisions would be required to assess how effectively they could be used to protect the aquifers.*

- *The Planning and Development Act allows provincial authorities to review local policy and provide direction as necessary. It is recommended that the province considers using this legislation to control land use policy and activity over the aquifers. Further work would be required to evaluate how this could be done most effectively.*

5. In addition to legislation allowing the province to exercise control over aquifer protection, municipal governments have substantial influence over land use activities in their jurisdictions. The review of municipal land use controls presented in this report allows for the following observations, conclusions and recommendations:

   - *Significant variability exists among the various development plans and zoning bylaws currently in place at the municipal level. While aquifer protection is dealt with comprehensively in some jurisdictions, it is nearly absent in others. It is recommended that the province examine a means of providing more direction and greater consistency in the preparation of municipal controls affecting aquifer protection.*

   - *Existing initiatives in various municipalities reflect a conscious effort by local councils to protect the aquifers. However, concern has also been raised over possible negative economic impact of not approving potentially rate paying activities. The result is an undesirable double objective at the municipal level. To insure objectivity in regards to land use developments over the aquifer, greater involvement by the province is recommended.*

6. A review of initiatives by other jurisdictions suggests that direct and indirect approaches to aquifer protection can be implemented. The direct approaches consist of Aquifer Management and Protection Legislation which enacts a permanent government program or an administrative body dealing with aquifers. The indirect approach consists of problem specific measures dealing with one or more aspects of aquifer protection through the use of agency guidelines. Of the two approaches presented, the direct approach is the preferred approach because:

   - *it would provide the long term commitment required to protect the resource;*
   - *it would include Aquifer Management and Protection Legislation encompassing all aspects of aquifer management and protection in one document;*
   - *it would ensure consistency in mitigative measures applied in various municipal jurisdictions.*

The indirect approach is less attractive because:

- *it requires interjurisdictional collaboration at various levels to enforce all aspect of aquifer management and aquifer protection;*
- *no models exist for how an indirect approach could be comprehensively implemented;*
- *the absence of legislation may cause aquifer protection to be more influenced by prevailing economic and political objectives.*

7. The indirect approach to aquifer protection should be seen as an intermediate step. It benefits from public support through awareness and provides a training ground for the development of appropriate measures. As a long term solution for protection of the groundwater resources, Aquifer Management and Protection Legislation is recommended.

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APPENDIX A
Program of Constraint Matrix

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OPTIONS DEVICE=APLPLUS LINESIZE=132;
LIBNAME UROE 'D:\UROE\';
FILENAME OUT 'D:\UROE\R2SENS.PRN' PRN 'R2VARS.PRN';
DATA A;
SET UROE.RATING2;
*
* filter out potential sand overburden using surficial geology
*    and clay map
*;
IF (SUR1=3 OR SUR1=6 OR SUR1=8 OR SUR1=10 OR SUR1=12)
   AND CLAY LT 1.5 THEN OVERB=1;
 ELSE OVERB=0;
*
* filter out areas where major aquifers have been delineated
* including the alluvium of the Qu'Appelle valley,
*;
IF DECM GT .5 OR DEFL GT .5 OR DEP6 GT .5 OR SUR1=2 THEN MJAQ=1;
 ELSE MJAQ=0;
*
* filter out areas where surficial geology suggests that
* minor surficial aquifers may be present
*;
IF SUR1=3 OR SUR1=6 OR SUR1=8 OR SUR1=10 OR SUR1=12 THEN MIAQ=1;
 ELSE MIAQ=0;
*
* filter out outcrops of major aquifers
*;
IF DECM=1 OR DEFL=1 THEN MJOC=1;
 ELSE MJOC=0;
*
* filter out 0-5 metre subcrops of major aquifers
* including Qu'Appelle alluvium
*;
IF MJOC=0 AND (DECM=2 OR DEFL=2 OR SUR1=2) THEN MJSCA=1;
 ELSE MJSCA=0;
*
* filter out 5-10 metre subcrops of major aquifers
*;
IF MJOC=0 AND MJSCA=0 AND (DECM=3 OR DEFL=3) THEN MJSCB=1;
 ELSE MJSCB=0;
*
* filter out >10 metre subcrops of major aquifers;
*;
IF MJOC=0 AND MJSCA=0 AND MJSCB=0 AND MJAQ=1 THEN MJSCC=1;
 ELSE MJSCC=0;
*
* for sensitivity mapping, the following categories were used:
* sens=1 a) major aquifer outcrops as surficial sand and gravel
*        b) major aquifer subcrops beneath 0-5 m of sandy overburden;
* sens=2 a) major aquifer subcrops beneath 0-5 m of clayey overburden
*        b) major aquifer subcrops beneath 5-10 m of sandy overburden
*        c) surficial sand which forms local aquifers;
* sens=3 a) major aquifer subcrops beneath 5-10 m of clayey overburden
*        b) major aquifer subcrops beneath 10 or more metres of sandy overb.;
* sens=4 a) major aquifer subcrops beneath 10 or more metres of clayey overb.;
* sens=5 areas where data is insufficient to assess sensitivity;
* sens=6 areas covered by major water bodies;
```

```
*;
IF MJAQ=0 AND MIAQ=0 THEN SENS=5 /*undefined*/;
IF MJSCC=1 AND OVERB=0 THEN SENS=4;
IF MJSCC=1 AND OVERB=1 THEN SENS=3;
IF MJSCB=1 AND OVERB=0 THEN SENS=3;
IF MJSCB=1 AND OVERB=1 THEN SENS=2;
IF MIAQ=1 THEN SENS=2;
IF MJSCA=1 AND OVERB=0 THEN SENS=2;
IF MJSCA=1 AND OVERB=1 THEN SENS=1;
IF MJOC=1 THEN SENS=1;
IF H201=2 THEN SENS=6;
*
* output new variables
*;
PROC PRINTTO PRINT=PRN;
PROC PRINT;
TITLE 'NEW VARIABLES CREATED BY R2FILTER.SAS';
VAR DECM DEFL DEP6 SUR1 CLAY H201 RAT2 OVERB MIAQ MJOC MJSCA MJSCB MJAQ
SENS;
*
* sort and output matrix for SPANS
*;
PROC SORT;
BY RAT2;
DATA _NULL_;
 SET A;
 FILE OUT HEADER=R2SENS N=270;
  PUT CASE 1-10 RAT2 11-20 SENS 21-30;
RETURN;
 R2SENS: PUT @1 '12345678901234567890123456789012345678901234567890'/
            @1 '1' @3 'CASE' @11 '1' @13 'RAT2' @21 '1' @23 'SENS' /;
RUN;
```

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